ROPES and ROPE DRIVING

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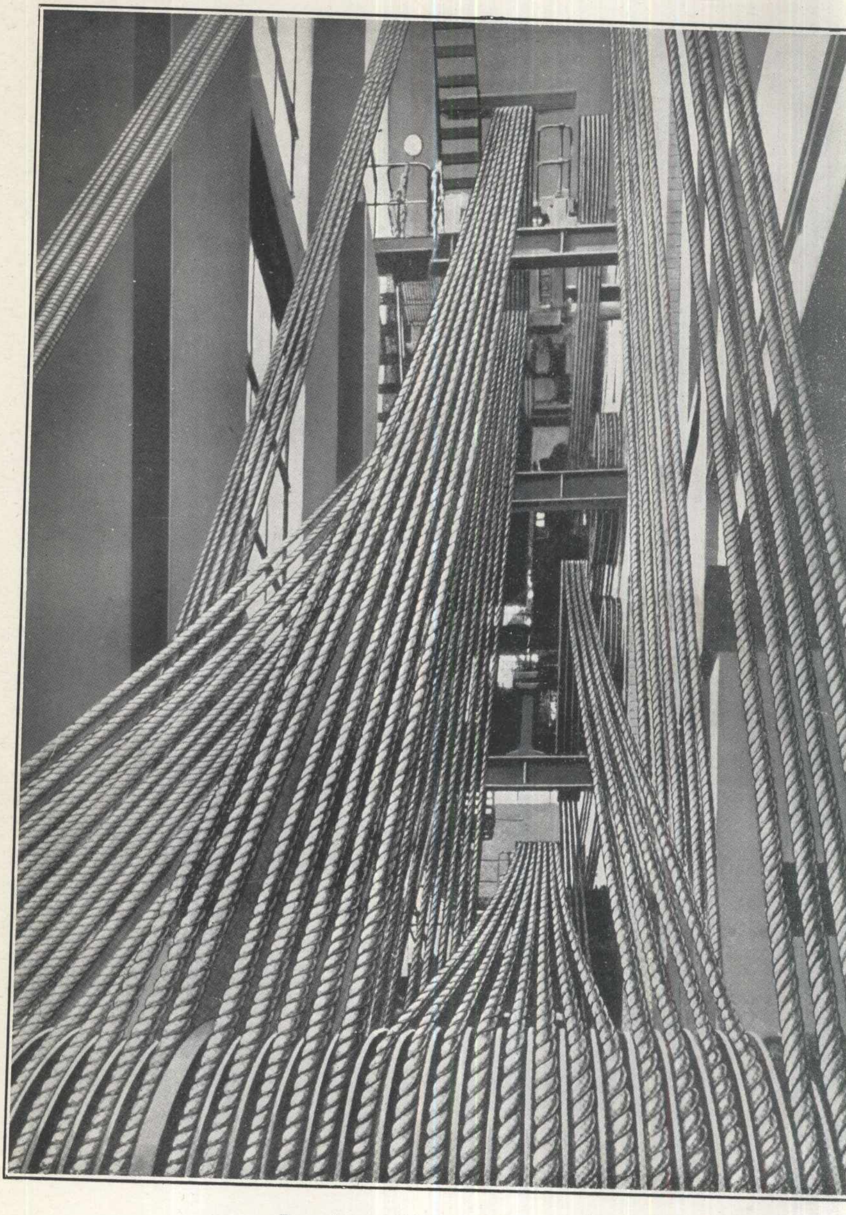

Rope-Race of Turbine-Driven Mill.
Capacity 2,300-2,900 *B.H.P.*
The entire Mill of seven storeys is driven through these ropes.

ROPES AND ROPE DRIVING

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"WIRE AND OTHER SPLICINGS"
"FITTING OF ENDLESS ROPES OVER GROOVED PULLEYS"
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FOREWORD

THE enormous growth and development of rope driving during the last decade has made most people in some way conversant with the methods of rope drives. It has been thought advisable, however, to supply duly authenticated and readable matter describing in general the basic principles of the system, together with a fairly comprehensive list of its applications and limitations.

The present booklet is the vanguard of this effort and will be supported at intervals by the several special sections mentioned in the context. Those whose thirst for knowledge is awakened by this book should apply for our other booklets, since it was not deemed advisable to mix descriptive matter with mathematics in a work such as this.

The attention of engineers is particularly directed towards Chapter VI. on Pulleys, where a vigorous protest is made against some malpractices which have caused endless waste and trouble in the past.

Even whilst this book and its companion volumes (which will be issued later) are intended to make power-users conversant with the principles of design in rope driving, we wish seriously to warn would-be designers that their path is beset by pitfalls. We extend a cordial invitation to all interested parties to consult our Technical Department about their rope driving questions, be they ever so small; our confidence to be able to advise all clients in their best interests is based upon over sixty years' experience.

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ROPES AND ROPE DRIVING

CHAPTER I.

HISTORY AND DEVELOPMENT

THERE is probably no single, simple commodity, apart from food, which has been more essential to progress and growth of any kind than rope. Right back past the dawn of history ropes and cords have been needed to bind and to hold, and we can trace their use also for power transmission far back in the story of the world.

The need for rope or its equivalent rudimentary ligature must have been felt by prehistoric man at an early stage in his development, and as his constructive intelligence emerged from the abysmal darkness of mere brutality the necessity for a suitable element whereby things could easily be fastened together must have thrust itself upon him.

Possibly Nature herself had ready to hand the first natural rope in the shape of the tough creepers which abounded in the primeval jungles. Utilizing these, the prehistoric man would be at once in a very superior position. He would stumble blindly on to the discovery that implements, weapons, etc., could be more easily made in pieces and then tied together; this, with other conveniences would rapidly be spread among the tribes until the discovery gradually became assimilated as an integral part of the System of Things.

The development from raw vegetable to the stronger hide and animal tissues would come as man, by his superior intellect and weapons, became master of the lower animals, and the reversion back to the original vegetable fibres would only come with more enlightened times when the art of spinning made possible the manufacture of a strong cord from this kind of material.

There seems to be very good historical reason to presume that the first rope drive followed naturally as the spark of human intelligence was slowly fanned into a brighter flame. This first rope drive to which we refer is the bow drill for facilitating the work of boring flints for arrowheads, implements, etc. Probably a quick result of this wonderful invention would be an uncomprehending discovery of Joule's law of the translation of mechanical energy into heat, and the bow fire kindler, used until recently by the American Red Indian, may have been the next form of primitive rope drive.

Later in the world's history we find the rudiments of rope driving in the ships' capstans and pulley blocks on all the seven seas. On land, the Oriental mind was quick to turn the rope drive to labour-saving advantage in such contrivances as the potter's wheel, the Indian lathe and the native endless water elevators, all of which machines contained the seed of an idea which has fructified with little essential variation up to the present time.

Leaving this interesting task of tracing the path of rope driving's progress through the ages, we must turn to the more important task of studying its growth during the Industrial Era, particularly since the advent of the steam engine.

The first recorded instance of a modern rope drive used to transmit power from its source to the place of its application occurred in a small rope works in the Eastern counties about 1835.

The idea here was to obviate the necessity of two prime movers at the remote ends of a long rope race by centralising the power supply and unifying the control. This was only rendered possible by the rope drive in the particular instance quoted, no other method of transmission at that time being practicable.

No popular attention, however, seems to have been given to this pioneer effort until rope driving had insinuated its way to an established position by other means. The particular drive appears to have achieved its purpose with singular success considering the handicaps to which it was subject. One cannot but wonder at the fact that the tremendous possibilities of such a development should never have suggested themselves to the ingenious rope-maker who installed the drive. It should, of course, be remembered that the drive was of the most elementary kind.

For nearly thirty years from this time, during which industry attained an immense national importance and power-driven factories and workshops were springing up all over the country, no further development is recorded in the transmission of power by ropes in the British Isles.

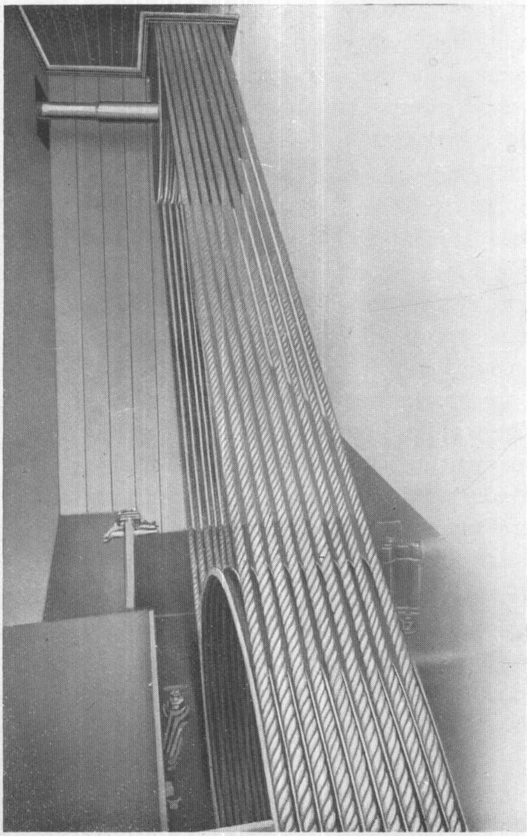


Fig. 1.
Falls Foundry Drive.

It has been stated that during this period several rope drives of a temporary nature were used in America, but there is no definite authority for any of these.

The history of the modern rope drive can be truly said to date from 1863, when a drive was installed at Falls Foundry, Belfast, which heralded the present vogue. This drive is illustrated in Fig. 1.

Following its installation, numerous hemp rope drives were put into commission among the flax factories around Belfast, and, by similarity of interests, the system was passed on to the jute spinning mills of Dundee and Aberdeen. From these places it ultimately travelled to the Lancashire cotton mills, where occurred the first important development in the system, and one which assisted largely towards the immense popularity it has now achieved.

This was the adoption of cotton ropes instead of the manilla and hemp ropes which had until now been used exclusively. The cotton spinners of Lancashire were to a large extent responsible for the adoption of cotton, but when once the superiority and economy of the new material had been proved, the rope-makers of this country gradually took up the cause, with the result that where hemp ropes started the great majority of ropes are now of cotton. The various reasons underlying this change will be discussed later ; we will content ourselves at the moment by stating that we, ourselves, were rather violently converted into warm supporters of the new fibre by the unfortunate results obtained in practice from hemp and manilla ropes.

Rope driving in cotton soon became the accepted standard for the large cotton mills in Lancashire, and with the meticulous care in design and maintenance that is so characteristic of their large main drives the system was, for the first time, given a really fair trial.

Formerly, rope driving had been used in cases of necessity. Only when a situation of unusual difficulty or complexity arose would men's minds turn for assistance to the rope, which, except for its inherent hardiness in withstanding severe and uncongenial conditions, would scarcely have withstood the disfavour bordering upon contempt with which it was often regarded.

Thus, in the past it had often been used only as a last resource, and then often under conditions which had proved too much for one or other of the more time-honoured methods of transmission. In such cases, if the rope drive successfully overcame the obstacles in its path it was running under conditions which absolutely precluded any possibility of really efficient or reliable service.

Thus, the rope drive was often placed at a disadvantage by reason of its superior qualities, for it is easy to see that after a drive had been running for a few years the recollection of the original difficulties would become indistinct, whilst the temptation would be always present to compare it with other systems of driving which flourished under much more congenial conditions, in, perhaps, the same mill or workshop. Naturally the other drives, which possibly had been totally unable to accomplish what the rope drive had thus achieved, received the popular though undeserved acclamation.

However, to be platitudinous, the success of rope driving and its rise to popularity during the last thirty years has been the reward of true merit.

Since the Lancashire cotton trade adopted rope driving and substituted cotton for other and less suitable materials, the history becomes an almost unbroken series of successful applications to all the multitudinous industries which utilise mechanical power in any of its forms.

All the time minor improvements in detail have been made ; the first drives were often installed with wooden pulleys ; these were soon discarded in favour of cast iron on account of the rapidity with which the grooves of the former were worn out of shape. This is not surprising, because even with cast iron pulleys manilla ropes can wear hollow the sides of the grooves in a remarkably short time.

The next important development occurred in America, where the Continuous System was patented by an enterprising firm of engineers. This continuous system, which will be described in detail later, consists of utilizing one rope only which is wrapped spirally round both pulleys, passing from groove to groove until all are filled, when the return is made via guide and tension pulleys to the starting point, which may be considered as the joint.

Thus, there is only one splice and one endless rope which repeatedly passes over all the pulleys and grooves, whilst in the

Multiple, or English, system the drive is made up of a series of endless ropes equal in number to the grooves on one of the pulleys, there being no guide, jockey or tension pulleys necessary.

The idea of the continuous drive, however, was by no means new. The principle involved by which it is different from the multiple system is that the friction between the flexible cord and a cylinder varies directly as the arc of contact. Thus, by passing the rope several times completely round the pulleys it is almost impossible for it to slip. This fact was appreciated and made use of by the famous architect, Sir Christopher Wren, two hundred and fifty years ago.

In Willis's " Principle of Mechanism " occurs :—

"A DESCRIPTION AND SCHEME OF DR. WREN'S
INSTRUMENT FOR DRAWING UP
GREAT WEIGHTS
FROM
DEEP PLACES.
May 5th, 1670.

> " Having considered that the ways hitherto used in all Engins for winding up Weights by Roaps have been but two, viz. : the fixing one end of a roap upon a cylinder or barril, and so winding up the whole coyle of roap ; the other by having a chain or a loose roap catching on teeth, as is usual in clocks ; but finding withall that both of these wayes were inconvenient ; the first, because of the riding of much roap in winding one turn upon another ; the other, because of the wearing out of the chain or roap upon the teeth, I have, to prevent both these inconvenience, devised another to make the weight and its counterpoyse bind on the cylinder, which it will doe if it be wound three times about.
>
> " But because it will then, in turning, scrue on like a worm, and will need a cylinder of a very great length, therefore if there be two cylinders each turned with three notches and the notches be placed alternately, the convex edges to

> the concave as in the figure here adjoyned, the roap being wound three times about both cylinders, will bind firmly without slyding and work up the weight with a proportionate counterpoyse at the other end of the Roap."

Notwithstanding the quaint method of expression, this invention of Sir Christopher's was the so-called American System of Rope Driving applied to the peculiar necessities of the time.

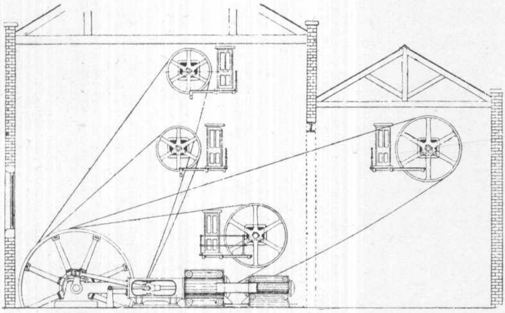


Fig. 2.

In any case, the capstan principle has been used from time immemorial to secure a grip between a rope and a fixed or rotating barrel. There are ingenious reconstructions extant which suggest that this principle was sometimes made use of by the Egyptians for hauling the huge stones of the Pyramid up the mammoth inclined planes to their allotted places.

The Continuous System has not gained much ground as the standard method of rope driving because for straightforward work it has many disadvantages, but no special features which carry important benefits. This will be discussed fully in a later chapter.

The growing popularity of electrical power and the advent and successful development of the high-speed steam turbine have exerted a powerful influence on the practice and theory of rope driving. Higher speeds have been called for and still higher speeds. What were once considered limiting values have been left behind in the quest of higher efficiency and greater economy. Fig. 2 is an illustration of a typical Woollen Mill main drive taken from a twenty years' old catalogue. Next, Fig. 3, shows the driving arrangement of a South Lancashire Cotton Mill. In the former case the rope velocity would be about 1,500 or 2,000 F.P.M. In the second case the rope velocity is over 7,000 F.P.M. Such velocities as the latter are not yet common on main drives, and in this particular instance rigorous precautions had to be taken to ensure that the ropes were not neglected, as is often the case. Still, these ropes give a life of twenty years even at this high velocity.

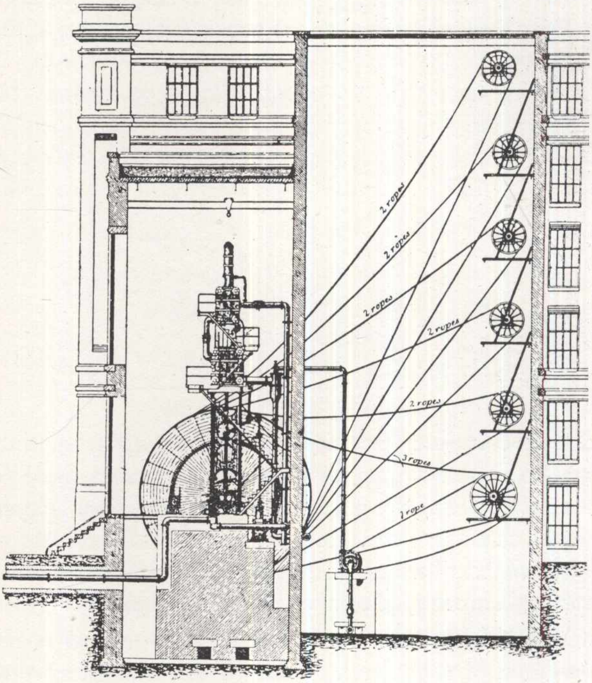
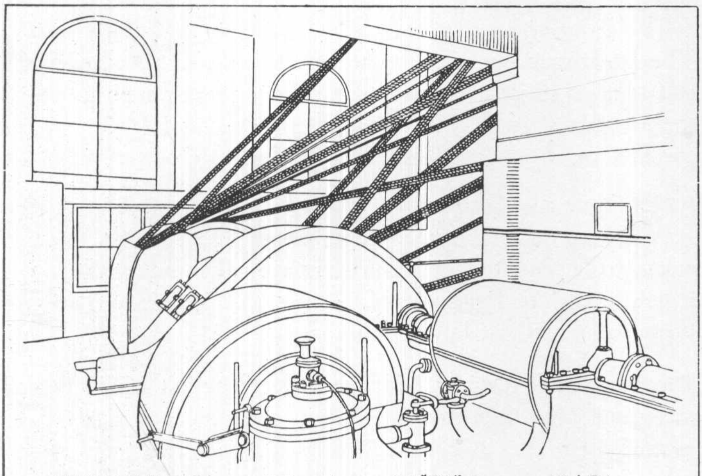


Fig. 3.

The general trend of progress in prime-movers is well illustrated by these two illustrations just mentioned, together with a third, Fig. 4, which shows the engine-room of a modern turbine-driven Cotton Mill. All these illustrations are drawn from actual working drawings or photographs.

The last illustration presents very nearly the last word in modern mill driving. It will be noted very clearly how the demand for economy in floor space and greater efficiency has influenced the lines along which development has travelled.

On the purely theoretical side little can be said here. In our separate booklet on the " Theory of Rope Driving " this subject is discussed at length. There is very little of historical interest to say with respect to it because no research of any magnitude was carried out until well in the present century.



2300 B H P. Geared Turbine , 44" P.I." Ropes 1¾ Diam

Fig. 4.

The invention of Sir Christopher Wren has already been mentioned. Reuleaux carried out some experiments on the stiffness of ropes and obtained empirical formulæ for the energy expended in bending ropes round pulleys. Since his experiments concerned only hemp ropes, they are of little other than academic value at the present time. Weisbach also obtained formulæ for the horse-power transmissible by ropes, basing his reasoning on the permissible ratio of tight to slack side obtained by the integral calculus :—

$$\frac{T_1}{T_2} = e^{\mu\alpha}$$

---

*See booklet on " Theory of Rope Driving."

Later, Professor Unwin has carried out experiments on the co-efficient of friction between rope and cast iron pulleys, as also have many other eminent scientists, but, unfortunately, through unknown variations in the governing conditions, no two experimenters appear to have obtained values which can be made to correspond.

Professor Unwin's values give a 45° groove co-efficient of friction of about 0·7 to 0·75, whilst Leboutre and others give a true co-efficient of about 0·075, which has an equivalent 45° groove co-efficient of 0·196.

The latter value is more nearly in accord with actual practice, but again it must be borne in mind it is hemp rope to which these figures refer. Cotton ropes have a slightly higher co-efficient, all other things being equal.

At one time it was commonly accepted that a velocity of 4,800 F.P.M. was the practical limit for ropes on a drive, above this velocity the centrifugal tension was assumed to reduce the power which may be transmitted, whilst the efficiency also was supposed to fall off beyond this speed.

Recent practice has absolutely disproved the old fallacy, which was plausibly supported by unimpeachable deduction. The root of the matter lies rather too deep for detailed explanation here, but this can be briefly said to rest on the fact that the old method of reasoning assumed a limiting value of only *one* of the factors affecting any rope drive, viz., the total tension of the rope. This, in reality, is one of the least important points to be considered within the limits of modern practice.

Old customs die hard, however, and to the present time, in spite of the fact that there are rope drives running very satisfactorily at velocities over 8,300 F.P.M. (at which point the old argument based on the old limits declares no power whatever may be transmitted by a driving rope), one occasionally sees it laid down as a law that the power to be transmitted by a rope attains a maximum value at a speed of 4,800 F.P.M., beyond which it rapidly falls back to zero.

A great amount of experiment on belting and belt drives also has some bearing on the theory of rope driving up to the point where both types are similar, but since in many things ropes and belt drives differ fundamentally, it is not wise to apply these results to our reasoning without great caution.

The publishers of this book hope from time to time to give fresh results of investigations carried out by their own Technical Department.

It is now realised that rope driving has come to stay, and that it has taken its place quite naturally amongst the other systems of transmission, old and new. By virtue of its accepted position it is now receiving more scientific attention, and at last the time is at hand when engineers generally admit that even a rope drive requires designing first of all.

The progress of rope driving as a system has been undoubtedly retarded by the many abuses to which its great convenience and adaptability have rendered it liable.

It is in an effort to get rid of these that this series of booklets has been written.

CHAPTER II.

MODERN SYSTEMS OF ROPE DRIVING

AS has been indicated in the last chapter, there are two principal systems on which rope drives can be arranged. There is the Multiple or English System, which, in the case of a straightforward drive, consists of two pulleys—a driving and a driven, each usually with the same number of grooves. These pulleys are parallel and in alignment, and a number of ropes are spliced endless round them so that each opposite pair of grooves is filled with one of the endless ropes. A good example of such a Multiple Drive is shown by the illustration, Fig. 5, of one of the largest rolling mill drives in the British Isles. This particular drive is in South Wales, and is one of two duplicate sets in a large tube-rolling mill. They have been running to date for over six years without the slightest trouble, even though they run in a gritty and variable atmosphere close to a number of re-heating furnaces. The peak load is estimated to reach 4,000 H.P., although the average may not be more than half of this.

It is not always that the drive is so simple in general arrangement as this. In mill driving especially many driven pulleys situated at varying distances and altitudes are driven from one driving pulley, which may be the flywheel, 20, 24 or even 30 feet diameter of a large reciprocating engine, or only a pulley about four or five feet diameter coupled to the low-speed shaft of a geared turbine.

A fine example of the former type of drive is shown in Fig. 6 (see page 20), the rope race of a Cotton Mill, whilst in Fig. 7 (see page 22), is shown a typical turbine drive. The frontispiece also affords a striking example of the latter kind of drive.

The continuous system to which some reference was made in the first chapter is somewhat different in principle. In the case of single open drives the driving and driven pulleys are parallel and in line as before, but instead of having as many separate endless ropes as there are grooves on one pulley, a

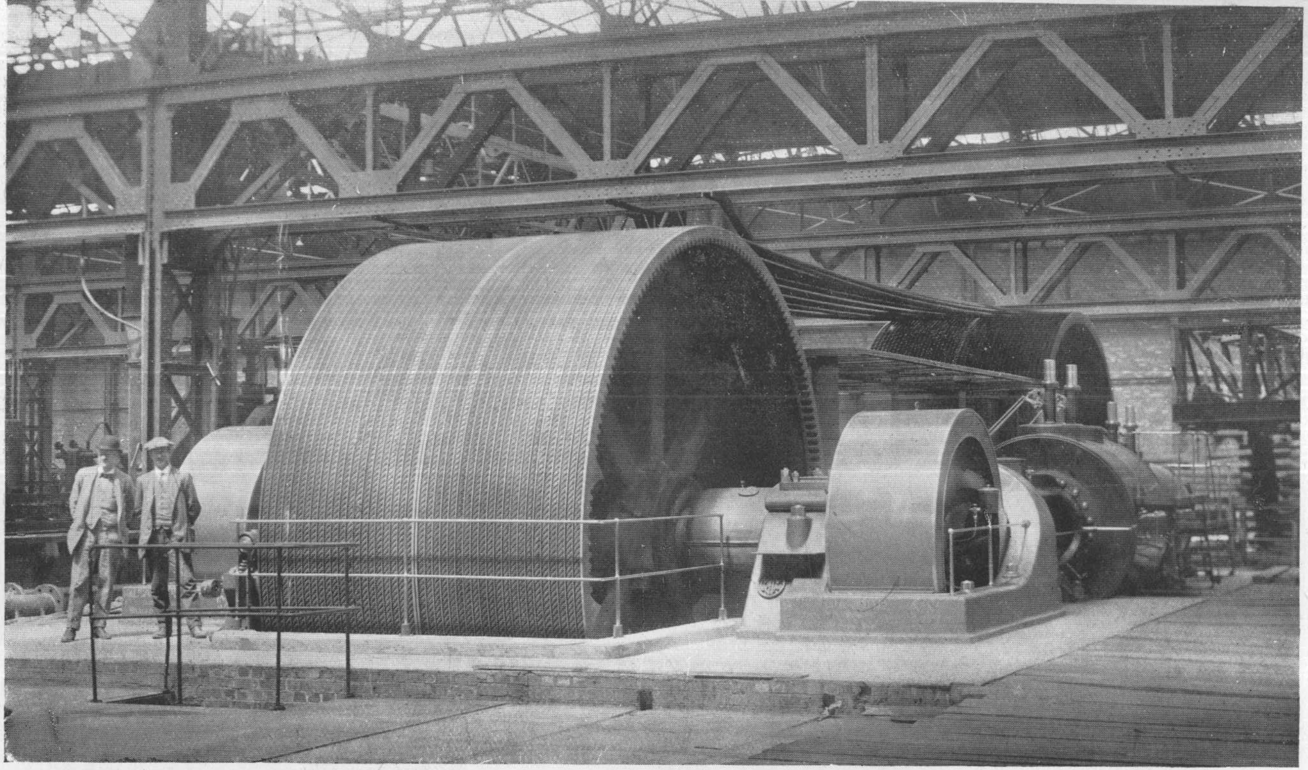


Fig. 5.
One of the largest Rolling Mill Drives in Great Britain. 4,000 H.P. from 42 2″ Ropes.

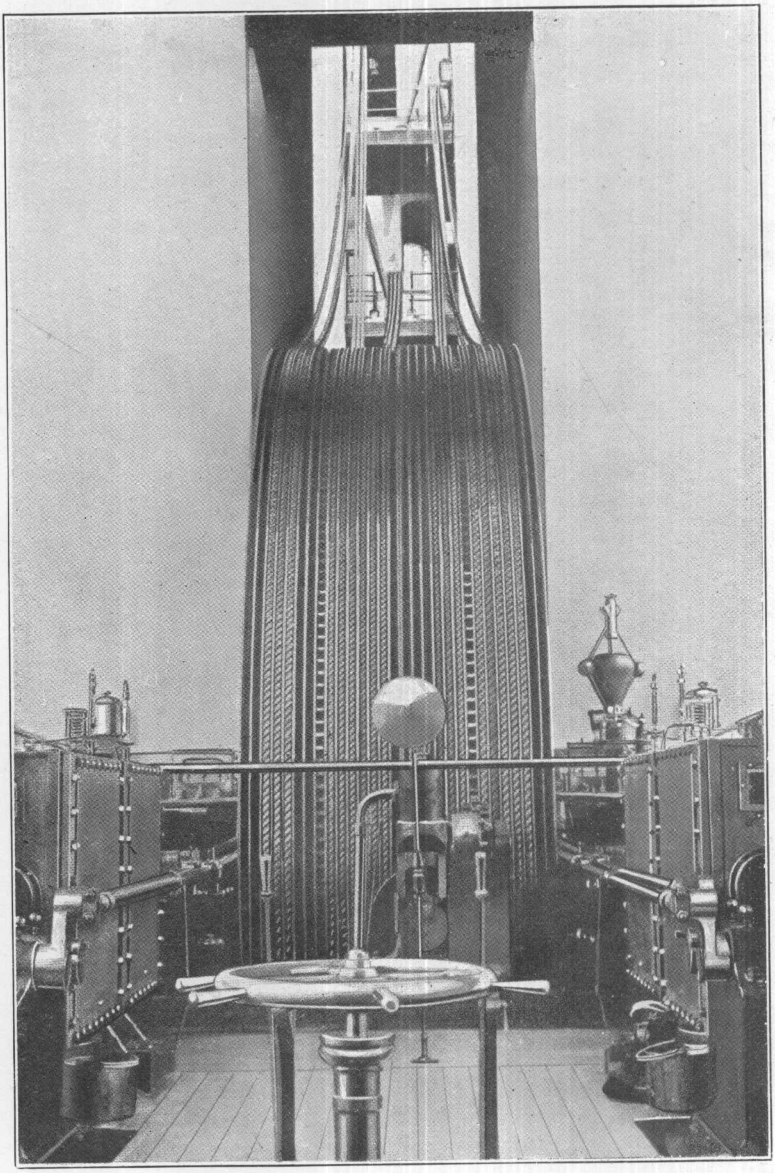


Fig. 6.
Rope Race in Cotton Mill Engine House.

single rope is threaded continuously round the pulley grooves, and also over auxiliary pulleys which are necessary to complete the circuit of the rope.

Commencing from an end groove on the driven pulley, the rope is passed over the corresponding groove in the driving pulley, then, instead of returning to the same point as in the Multiple System, it is returned to the *next* groove on the driven pulley. The slack side is thus returned one groove out of true alignment ; this is repeated until the rope comes to the last groove on the opposite side of the driving pulley. From here it has to be returned to its starting point, and at the same time provision must be made to take up the accumulated stretch from all the tight sides. This is usually done by the aid of two guide pulleys and one automatic tension pulley, as shown diagramatically in Fig. 8 (see page 23), when the drive is of the simple, open, horizontal type. A photograph of an actual installation is reproduced in Fig. 9 (see page 24).

With compound drives, that is to say, drives with more than one driven pulley, it is generally advisable to have one rope and separate tension pulley to each drive, although this is not essential. In no case, however, should more than 8 or 10 laps of rope depend on one tension pulley, otherwise this will have to exert too great a stress on the rope, with consequent shortening of its life. Not only this, but if the number of ropes to one tension pulley is very much in excess of the above limits, the drive will not function properly except under abnormal conditions.

A photograph of an installation on the continuous system is reproduced in Fig. 10 (see page 25). This is at a large grain elevator where the drive has to ascend to the topmost storey, a circumstance which rendered inadvisable the usual multiple system. The sliding tension pulley and carriage with the necessary return guide pulleys can be seen clearly at the top of the illustration. Another instance of vertical driving where the continuous system was advisable is shown in the next illustration, Fig. 11 (see page 26).

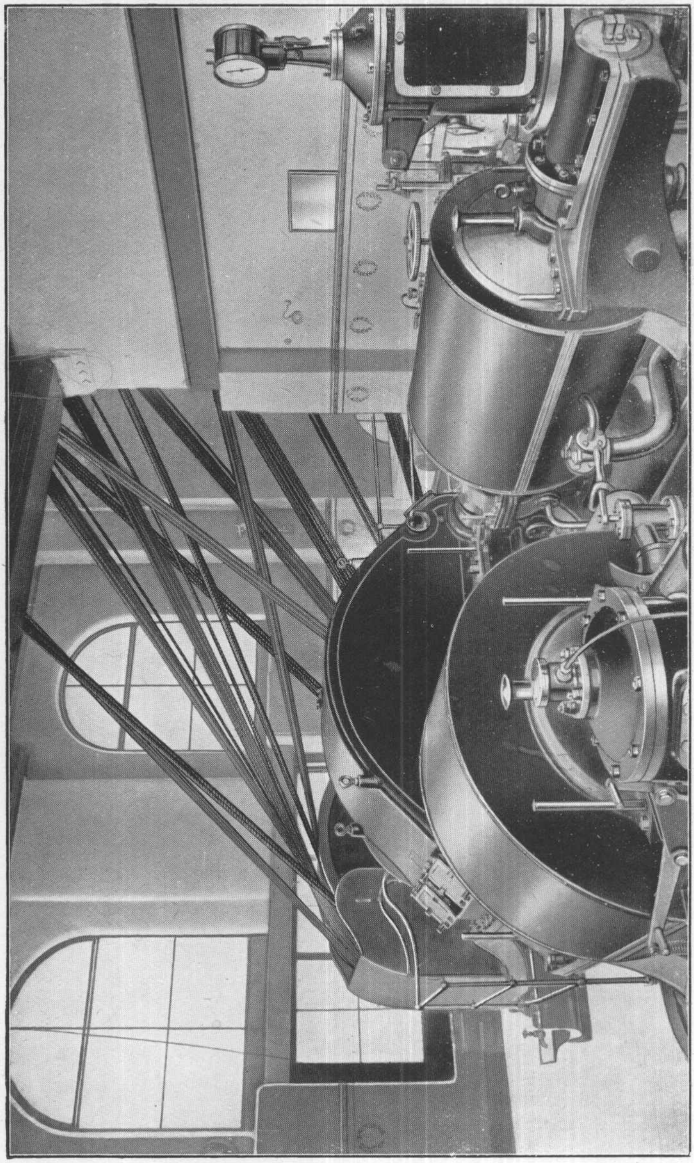


Fig. 7. Rope Drives from Steam Turbine.

The continuous system was originally put forward as a competitor of the multiple system, it being claimed that with the new system greater precision and efficiency could be obtained. This was a great mistake, for even though the continuous system of rope driving was a very ingenious adaptation of an old principle, it could never hope to replace the simpler multiple drive owing to the fact that the former method did not bring forward any really material advantages of its own to counterbalance one or two very obvious inconveniences. Chief amongst the latter is the danger of sudden breakdown to which the continuous drive is more or less subject; the rope being continuous, failure at any point immediately throws the drive completely out of action.

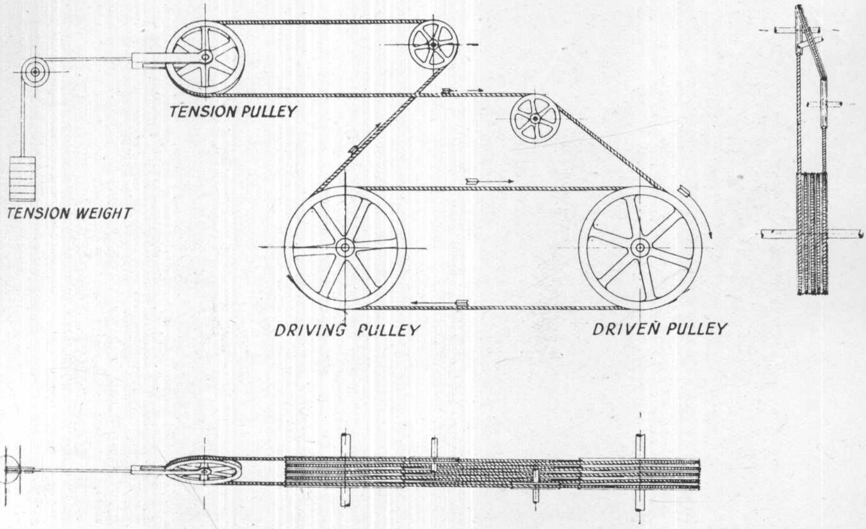


Fig. 8.
Diagramatic arrangement of Continuous Drive.

Contrast this with the unique reliability of the multiple system. Here we may have on a main drive any number from four to forty, or even more ropes, each separate and independent of the remainder. Only by accident or rare coincidence can more than one rope fail at once, and the result of removing one rope would seldom be sufficient to stop the drive from running.

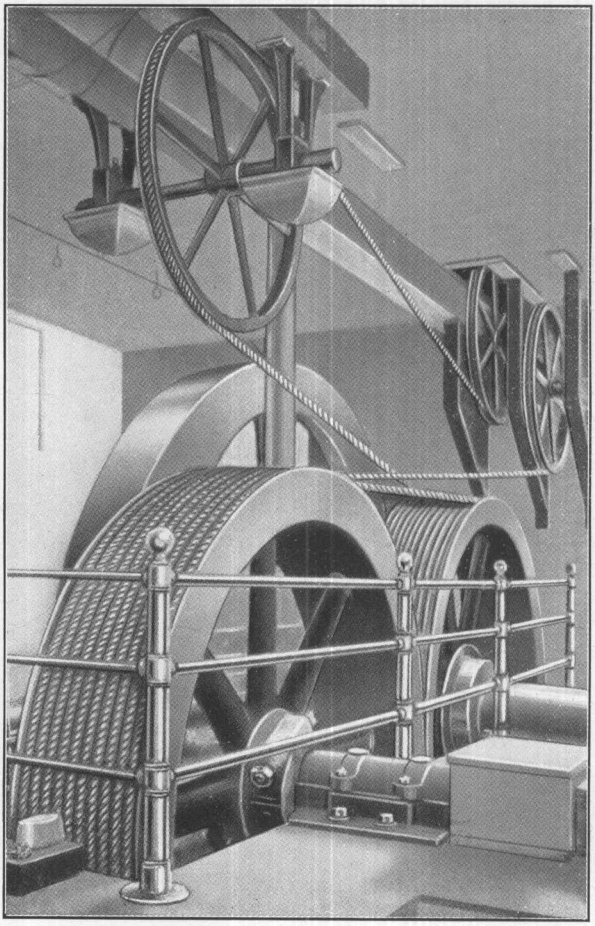


Fig. 9.
A modern Continuous Drive with very short centre distance.

A word of warning here: It is sometimes found that rope drive users allow their ropes to run right up to the last, their first intimation of this being the complete failure of one rope which may under these circumstances bring down with it other, sound ropes. This is due to sheer negligence, since even a worn-out rope gives ample warning of imminent failure long before the rope comes asunder. A brief glance is quite sufficient to reveal this state of affairs to any person taking an intelligent interest in the ropes.

This is one of the things rope driving has to suffer on account of its complaisance. A correctly designed and installed drive gives so little trouble that sometimes even the most elementary precaution is neglected.

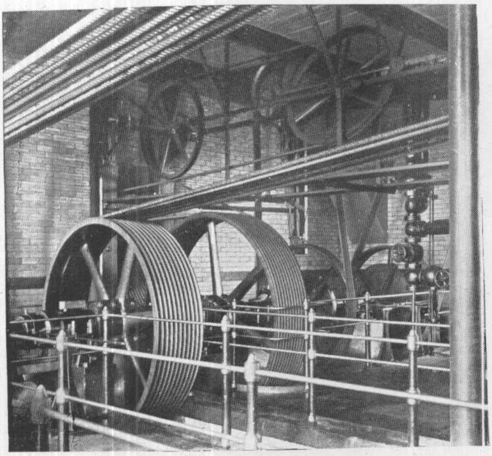


Fig. 10.
Continuous Drive in Grain Elevator.

Now, ropes, like most things, do not last for ever, and a time comes when they will fail. When a rope is about to fail, evidence of this is given by a sudden and abnormal degree of stretch extending over, perhaps, several days. A more urgent warning is when a few inches of one of the spliced strands comes free from the body of the rope. Even in this condition, however, ropes have been known to run for some hours without failing completely, although a rope in this condition should be cut down at the earliest opportunity. A failing rope should never be left to take its own course, because a rope coming apart at full speed is liable to create trouble in its immediate neighbourhood.

This, however, is not to be compared with the havoc which may be wrought by a rope being allowed to pull apart when running at speed on a continuous drive. Therefore, these drives are usually provided with an automatic alarm device which is set to give a strident, audible warning when the rope is enlarged or frayed at any point.

This point just considered constitutes one of the main arguments against the continuous drive and in favour of the multiple. An occasional inspection by an attendant is all that is necessary to avoid trouble with the latter system, and when a rope *does* fail, a few moments' stoppage, at most, is all it entails; the drive can run on quite safely for long periods, minus as many as 25 or 30 per cent. of its ropes, and in an even more attenuated condition for short periods if the necessity is imperative. For drives difficult to inspect when running, the provision of an automatic warning device is simple and inexpensive.

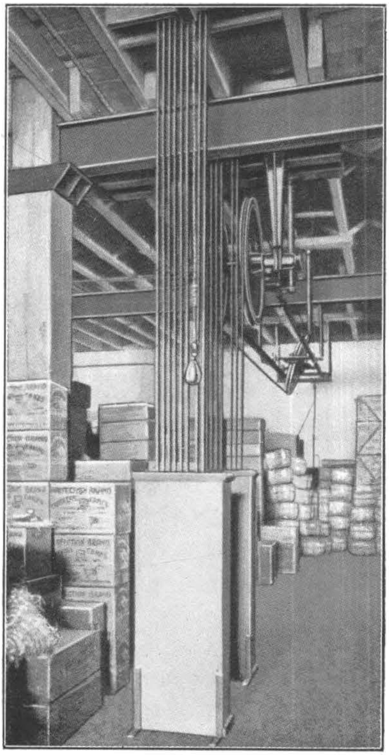


Fig. 11.
Vertical Continuous Drive.

Records go to show that the time lost due to rope failure in American Mills driven on the continuous system is over one hundred times as great as the amount lost in England due to the same cause on Multiple drives.

As regards the point often put forward by those specially interested on behalf of the continuous drive, that it is more positive in action than the multiple system, it should be remembered first of all that perhaps absolute precision of the kind implied here is not so great an advantage as it might seem. There should be no misunderstanding, however, about one point, namely, that a correctly designed multiple drive is absolutely positive well beyond the limits within which it is intended to run. This being the case, it is hard to understand what more can be desired.

With the continuous drive slip is very nearly impossible if there is any considerable number of laps of rope. Thus, a sudden shock or overload of dangerous magnitude has no safety-valve. It *must* be transmitted to and through the rope. With the multiple drive, on the other hand, whilst ample margin is provided for overloads which may be developed temporarily in the ordinary course of events, yet should these reach dangerous proportions, relief is immediately afforded by slip between ropes and pulley.

The claims that have been put forward for a higher efficiency with the continuous system than with the multiple under similar conditions do not bear close examination.

As is explained in our booklet on the " Theory of Rope Drives," the efficiency of a drive is increased with greater tension in the rope due to the power transmitted and decreased by the number and severity of the bends to which the rope is subjected. All conditions being the same, the tensions in two similar drives on the two systems would be equal for equal powers transmitted. Any excessive tension due to a heavy tightening device would only have the effect of adding to the wear on the slack side of the rope, but with this system of driving the degree of bending in the rope is increased by the additional guide and tension pulleys, and this tends slightly to reduce the efficiency.

Actual experimental observation does not distinguish any appreciable difference in efficiency between the two systems.

There are, however, a number of special circumstances under which a multiple drive cannot function properly. These are explained in detail in our booklet on " Specimen Drives." In some of these cases the continuous system can be applied

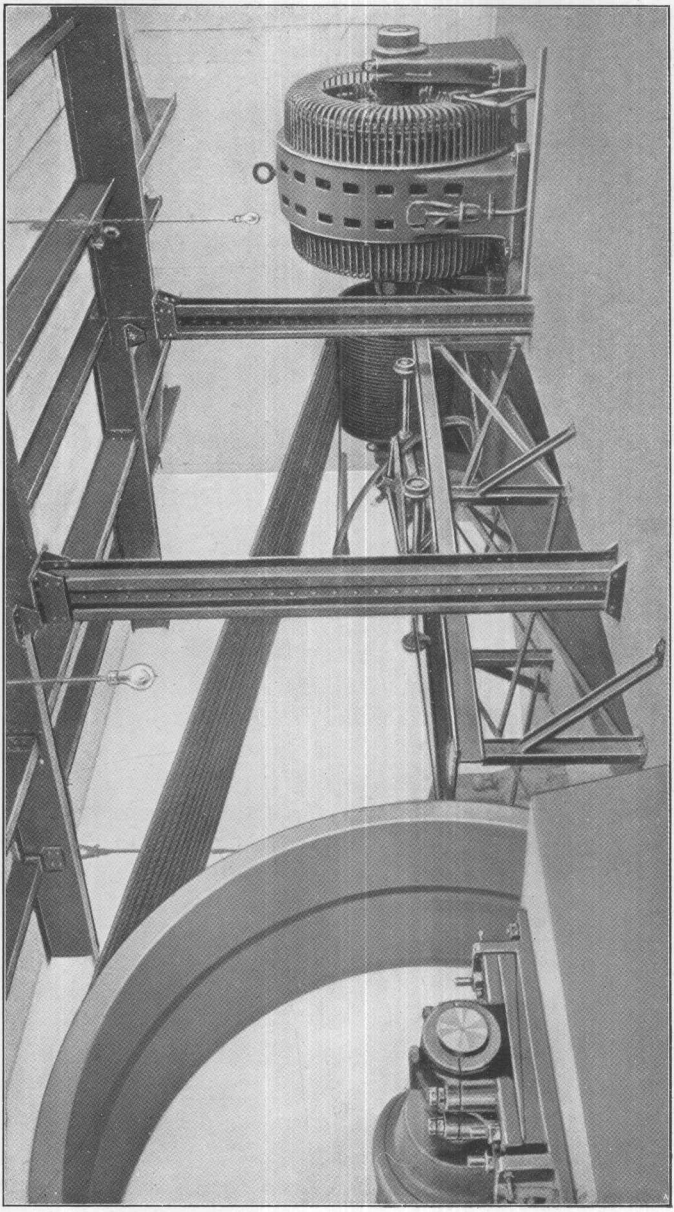


Fig. 12. 1,000 *H.P. Continuous Drive.*

with success if reasonable precautions are taken. Thus, even though an analytical comparison of the two systems is undoubtedly in favour of the multiple drive where this can be satisfactorily installed, it should be remembered that a few peculiar combinations of conditions prevent this and so render the continuous drive advisable. The short centre distance, as in the case illustrated in Fig. 9, combined with a limited width and high power, is an example of this.

In figure 12 is illustrated another continuous drive, selected rather to show another method of arranging the tension pulley than as a representative instance of the suitability of the system. As a matter of fact, in this particular case a multiple drive could have been installed, if desired, with perfect satisfaction. The tension pulleys on this drive are arranged within the compass of the drive, thus saving space.

The decision when it is necessary to instal a continuous drive should be left to the expert, but there is no reason on earth why the more complex and less reliable continuous system should be adopted for rope driving if the multiple system may be used.

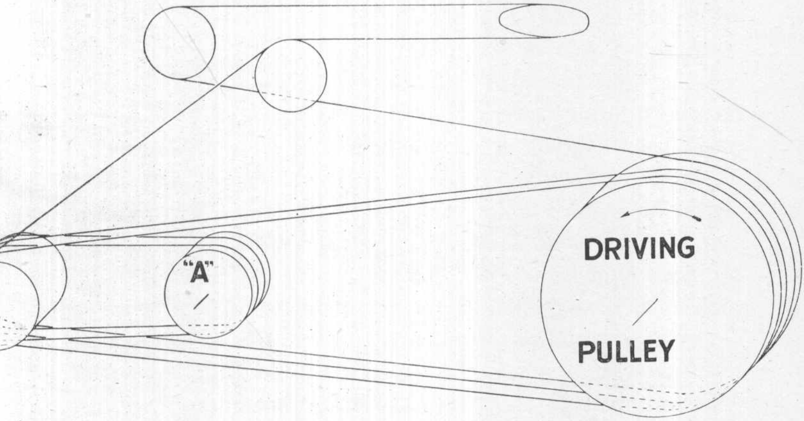


Fig. 13.
Diagramatic arrangement of Winder-Pulley System.

There are no other general systems of rope driving, although a device for improving the grip between ropes and pulley, which is really an extension of the principle upon which the continuous system depends, is occasionally seen in use.

This device consists of wrapping the rope of the continuous system round a winder pulley parallel to the driven pulley, as " A " in Fig. 13 (see page 29).

Each lap of rope thus doubles its arc of contact on the driven pulley. For most conditions such an artifice as this is totally unnecessary, but where, for instance, the driven pulley is very small in relation to the driving pulley and the load is subject to severe shocks, it may be beneficial to take advantage of this idea ; or again, in cases where the rope speed is very low and torque is more important than power. The principle is used extensively, or rather *was* used extensively on street cable railways, the take-off to the tension arrangement as in Fig. 13 corresponding to the haulage cable.

CHAPTER III.

ADVANTAGES OF ROPE DRIVING

ROPE driving is a quasi-positive method of transmission, being quite distinct from belts and other friction drives, in so far as these are almost invariably accompanied by a degree of slip.

Yet rope driving is not mechanically positive in the manner of toothed gearing, but positive only within limits which should never be exceeded in the case of a well designed drive, except under extraordinary and unforeseen circumstances.

The Transmission of Power by Ropes is thus a " middle way " between the inefficient friction drives on the one hand and the expensive toothed gears on the other.

The grip is obtained between rope and pulley by virtue of the back tension due to the weight of the slack or trailing span, which is considerably increased as a resistance to slip by the " vee " groove in which the rope rests on the inclined faces.

The advantages of rope driving can be best tabulated, commencing with :—

RELIABILITY AND LONGEVITY. This is generally placed first among the advantages of rope driving because its superiority in this respect above other forms of transmission is unique. In the first place a drive of any magnitude consists of a number of quite independent ropes. Drives have been installed with as many as eighty ropes on one pulley. Now, in designing a drive, margins of safety are allowed as in all other branches of engineering, but in this particular class of work the margins allowed are greater than those commonly used in other directions. This does not signify that practice in design of rope drives is arbitrary or extravagant. The wide margins of safety are obtained indirectly. All design must take into account the economical features of the case. Thus, it does not matter that a drive may be installed which will merely run, it must be made to last for a certain reasonable time, or else the future of the system would be in jeopardy. This entails the consideration of wear, which is actually of more importance than strength, provided, of course, the components of the drive are made sufficiently strong to withstand the stresses that will be put on to them.

Obviously, however, a design which ensures a certain working life will possess greater margins of reserve strength than if static stresses alone were taken into account.

Taking a typical example, the actual stresses in the rope performing its full duty are only about one thirtieth, or at most one twenty-fifth, of its ultimate strength. Any accidental cause increasing the load to a magnitude which might subject the ropes to dangerously high stresses is automatically safeguarded by the slipping point of the ropes in the grooves. Fortunately, the co-efficient of friction between the rope and the pulley, above a certain normal pressure, increases as the velocity of sliding increases, so that slip of this kind is not progressive. What happens is that dangerous excess of load energy finds immediately a safe outlet in a moderate degree of slip—the only real slip which occurs on a properly designed drive.

This occurrence is, of course, quite a rare one. Normally, a drive transmits its power positively with a large margin of reliability necessary to keep the wear on the ropes within economical bounds. This question is dealt with in a more technical way in our booklet on " Theory of Rope Driving."

Thus, we see that we have a double security against breakdown. The composite drive consists of a number of independent ropes, of which more than one will rarely fail at once due to natural causes. Should a number of ropes for any reason be removed from the drive, the remainder possess sufficient surplus of strength and adhesion to the pulleys that they can continue to transmit the power for considerable periods.

The interrogative mind at once wishes to know why was the drive not initially provided with only this small number of ropes, since they are capable of doing the whole work. The explanation is " wear." The smaller number of ropes can perform the full duty of the drive when urgent necessity demands it, but they would then be loaded to a degree greater than is economically sound for a permanent drive, and the rope is being used up at an accelerated rate.

This is not important, however, to a manufacturer whose main interest lies in keeping his shafting revolving and his workhands profitably employed. A few months less life out of the ropes for this reason due to an accident is negligible in comparison to, perhaps, only half an hour's stoppage of an entire factory.

In the case of a flat belt drive of any kind, if the belt breaks, all connection between prime mover and machinery is severed until the belt-man has been found and the belt repaired and replaced. With chain and gear drives, the frequency of breakdowns may be more remote, but the inconvenience in such an event is very much more intense and protracted. Electrical drives are not yet by any means immune from the common weaknesses of this sort to which all machinery is heir, and records could be quoted of large factories which have had to revert, at considerable expense, to rope and other mechanical drives after trials with the universal electrical drive.

One of these was at a large textile factory in the Midlands, in which a large room of heavy doubling frames each consuming over 12 H.P. normal load was originally driven by individual electrical motors direct coupled to the tin-roller shafts. A high speed vertical engine coupled up to any alternator with a capacity of somewhere about 600 H.P. was the power unit.

After running less than four years, the power unit, transformers, motors, and everything were thrown out and line-shaftings installed with a new main rope drive from a reciprocating engine. The frames were each driven in a manner similar to those shown in Fig. 56, page 93, except that two ropes were used on each drive instead of one. The drives were by "P.I." Ropes over the "Ruscoe" Patent Adjustable Gallows Pulley Bracket on to Weilding Patent Friction Clutches on the tin-roller shafts. The task of conversion was put in our hands, and, apart from the minor mechanical difficulties inevitable with a contract of this magnitude, the new drives have been perfectly satisfactory. Production has been increased by the change and running costs considerably reduced.

In Chapter IV., Fig. 33, there is an illustration of a short centre drive in a Scottish Jute Mill which has been in commission for about 38 years, the second set of ropes installed about 16 years ago still functioning efficiently.

In a Worsted Spinning Factory in the Keighley district there are ropes running to-day which have given absolutely no trouble, faithfully performing their allotted task, month in and month out, for over 36 years.

Innumerable instances could be quoted of cases of longevity and reliability similar to these. Among more modern installations there is the turbine drive shown in Fig.7, which has been running for over nine years at present, and has scarcely cost one pound per annum in maintenance and repair costs, stoppages for rope trouble being unknown. The ropes are good for many years' service yet.

Fig. 14 shows the engine house of a Lancashire Cotton Mill where ropes have run for about 16 years to the present time. On another engine of an older type at the same mill, ropes have lasted 28 years. All ropes are still running well.

Another example of reliability combined with longevity is illustrated by Fig. 15 (see page 36), where the conditions are much more difficult and severe than those just quoted. This is a wire-drawing mill driven from engine by ropes as shown; the average life of the ropes here has been about eight years, which is highly creditable under the particular conditions.

One final example is given in Fig. 16 (see page 37) of another rolling mill, where no inconvenience has been experienced due to the ropes. The conditions here, as can plainly be seen, are extremely uncongenial, yet a life of over five years has been obtained from the ropes.

These truly representative examples which have been quoted compare very favourably with the average lives obtained from

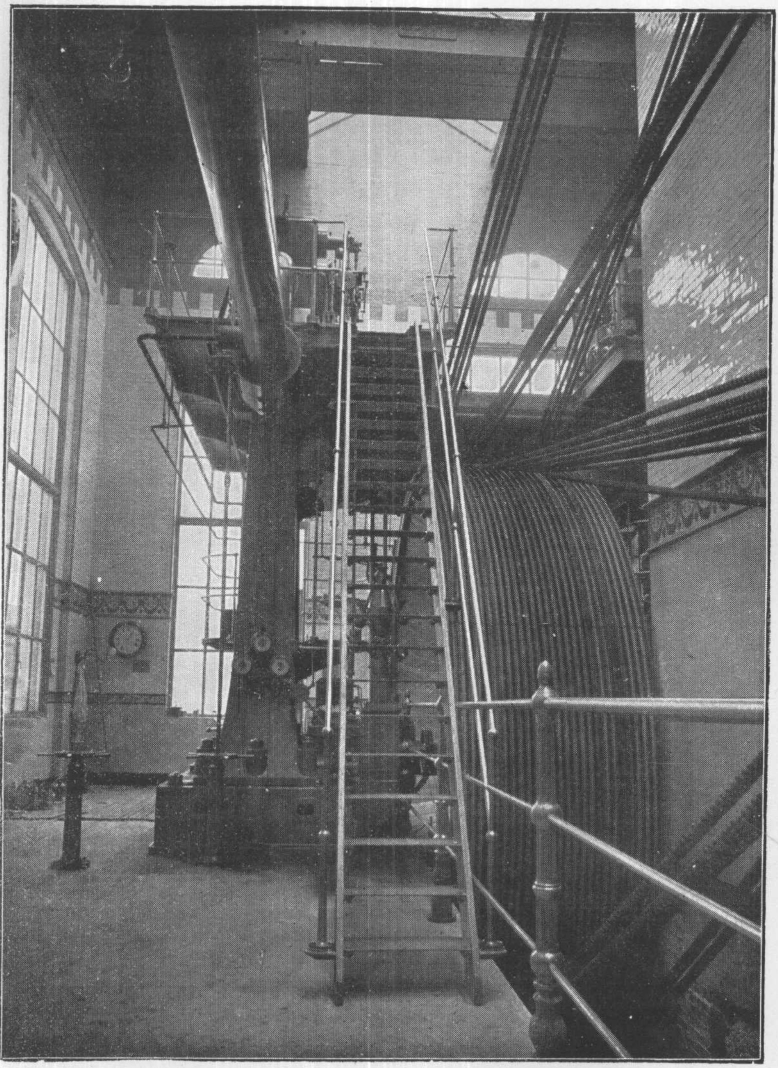


Fig. 14.
A typical example of efficiency and reliability.

other modes of transmission. It should be remembered that the pulleys of a cotton rope drive, provided it is free from slip, as it should be, are practically permanent. This is by no means the case with gear and chain drives, where the sprocket may scarcely last the life of two chains, whilst the average life of the latter is nowhere near some of those quoted previously for rope drives.

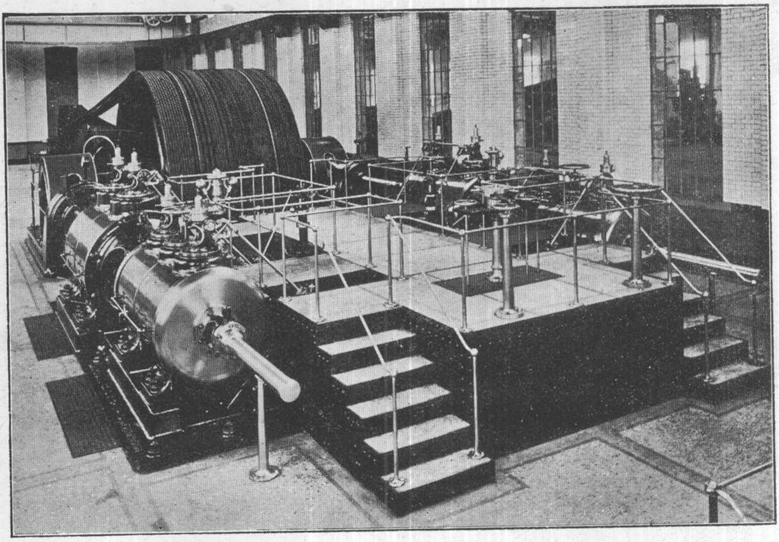


Fig. 15.
Engine House of a Wire-drawing Mill.

Also, it should be borne in mind that the efficiency, reliability and general utility of a rope drive continue unimpaired right up to the last, the efficiency, in fact, actually increasing, and this cannot be said of many of the other methods of driving.

Next in order of importance amongst the natural advantages of the system of rope driving we have :—

ECONOMY. This can be subdivided under three headings : (*a*) economy in capital cost, (*b*) economy in running cost, and (*c*) economy in space.

The cotton rope drive is economical in capital cost because even though the necessary grooving of the pulley rims adds somewhat to the cost of manufacture of these, the ropes themselves are very considerably cheaper than the many kinds of flat or special belt manufactured. Except within the small limits of very low velocity combined with very short centre-distance, the rope drive is much cheaper per horse-power transmitted than the chain or gear drive.

Fig. 16.
Large Sheet Rolling Mills.

For centre-distances up to 200 feet, the system is cheaper to instal and run than electrical plant, whilst for normal distances, say from sixteen to sixty feet, the advantage is still more marked. In cases of angular driving and for awkward situations generally, within the above limits, the same observations hold good.

In our booklet on the " Driving of Spinning Frames," we quote figures from Kemp's Engineers' Year Book in which it is clearly shown that with three alternative methods open to the designer for driving any given mill or factory, the mechanical drive with ropes throughout is cheaper than either a private power plant with electrical transmission or purchased electrical power with transformers on site, and the usual motors to drive the machinery. Whilst the capital cost of the latter method of driving is lower, the running costs are so high that they would, at pre-war rates, swallow up in five years any saving thus effected.

In comparing the rope drive with the belt drive for running costs, a number of things have to be taken into consideration. First of all there is the fact that the ropes last longer and require less attention than belts. This means lower maintenance costs and depreciation charges. Then we must also remember that the rope drive should be, and usually is, quite positive except for a slight degree of creep common to all transmissions with elastic media.

The flat belt drive, however, is very rarely positive, and in drives to high-speed machines, etc., it is never safe to reckon on the development of full calculated speed ; five per cent. is usually allowed for slip under these conditions, whilst on main drives possibly a smaller degree occurs on the average. There is on this account alone a saving of from three to five per cent. on the power bill with the rope drive as compared with the belt. Then, as regards the question of efficiency, neglecting slip, the rope drive again has an advantage which is probably not less than five per cent. in the mean value. Accurate figures for the efficiency of belt drives are very difficult to obtain, but in our booklet on the " Theory of Rope Driving " the subject of the efficiency of the rope transmission is treated at length.

The rope drive would therefore have an advantage of about eight or ten per cent. in efficiency, which, of course, means a saving of so much on the power bill, over a belt drive, running under the same conditions.

This advantage can be pushed farther, however, because the efficiency of a rope drive increases with velocity within practical limits. A belt drive cannot be run at much higher speeds than 3,000 or 3,500 F.P.M. without excessive slip, whilst velocities up to 6,000 F.P.M. are quite common in rope driving. For this reason the design for a rope drive can be pushed beyond limits of speed impossible in designing a belt drive, with the result that advantage is obtained of the still higher efficiency obtainable at these velocities.

In comparison with the link belts and steel chains, the rope drive is much more efficient. The flexion of the cotton rope is largely fibrous and almost entirely elastic, whilst the bending of chains and link belts is merely the rotation of bearings round pivots, every relative movement of which consumes energy wastefully.

The electrical system is often supposed by the layman to be the very last word in modern practice so far as efficiency and economy go. A few representative values of efficiencies actually realised in practice by electrical plant may be of interest in this direction. A large generator of over 500 H.P. will be performing its work very creditably if its efficiency is as high as 94 or 95 per cent. Should the normal output of the machine be lower, say about 100 H.P. to 200 H.P., an efficiency of 90 per cent. under ideal conditions is the highest usually attained in practice.

Similarly with motors, the efficiency curve in Fig. 17 (see page 40) shows that a 10 H.P. d.c. motor will only have the low efficiency of 83 per cent., whilst a 50 H.P. motor would not have a higher efficiency than 88 per cent. These values are for motors of the given output developing their full load, the disadvantage of a motor of ordinary design being that the efficiency falls off rather rapidly at fractional loads. Now, it is very seldom that a motor driving a machine works at its full capacity, for the simple reason that to do this would lead to very serious trouble. Many kinds of machinery require extra power for the mere operation of setting them into motion from rest and after stoppages, such as week-ends, owing to the viscosity of the lubricant between all the bearing surfaces having increased, the power taken by machines is considerably above normal until they become warmed up again. Curves of power readings demonstrating this effect are shown in our booklet on the "Driving of Spinning Frames."

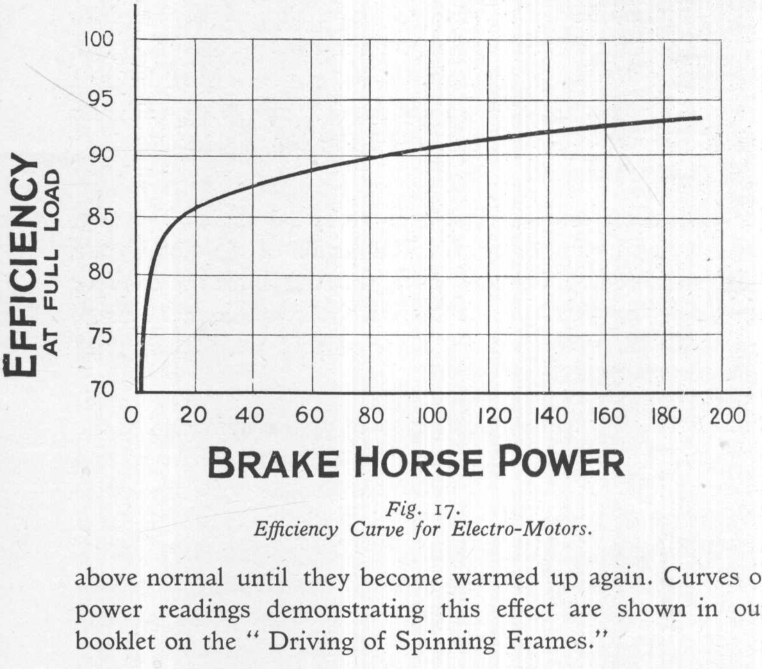


Fig. 17.
Efficiency Curve for Electro-Motors.

Hence, electro-motors either driving individual machines or driving blocks of machinery through line shafting must of necessity have a capacity sufficient to cope with these extra demands. The result is that for the major portion of their working hours they run underloaded and their efficiencies are even lower than as shown by the curve in Fig. 17.

Taking into account generation losses, transmission losses and conversion losses in the case of a works with its own generating plant or the transmission, transformer and conversion losses in the case of one purchasing power from an outside source, the efficiency in either case will be much below that of a modern mechanical drive with ropes throughout.

The high-speed geared turbine drive similar to that illustrated in Fig. 7 appears to be a promising and economical method of mill driving.

Manufacturers, however, often consider that the actual efficiency of the method of driving is negligible in comparison with the effect it has on production, the manufacturing costs per unit of goods manufactured being affected much more in proportion by a slight rise in production than by a small saving in power. We affirm definitely that production is increased by the adoption of rope driving, some of the reasons being discussed later in this chapter under various headings. The reader is also referred to our book on the " Driving of Spinning Frames," wherein the beneficial effects on production of the adoption of rope driving in all kinds of textile mills is fully explained and proved. The mean value of this increase, from a large number of installations, is approximately eight per cent.

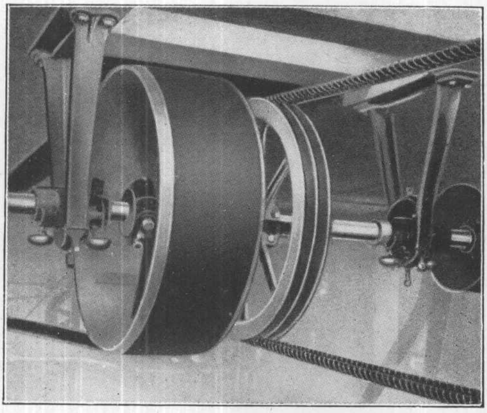


Fig. 18.
This belt only transmits 75 *H.P. against* 80 *H.P. by the two ropes.*

One factor already dealt with, but which has an important influence tending to increase production, is the immunity of rope driving from sudden or unexpected breakdown and stoppage.

The illustration, Fig. 18, affords a striking illustration of the greater economy of space offered by rope drives over belts. This is a feature of considerable importance, not only the more obvious advantage of saving floor space, but also the indirect advantage of less interference with lighting. In Fig. 19 can be seen a typical ring frame room in a spinning mill. The lighting, as is often the case, comes from the side, and the frames must be driven at the end nearest the windows. The necessity for the latter arrangement is not always present, but occurs in the majority of cases. Ropes occupying so much less space than belts were a very decided improvement here on account of the better light obtained. This is true in a great many other circumstances, as who has noticed the jungle of belts and countershafts almost obscuring the daylight in rooms crowded with machinery can well testify. Better natural lighting tends towards economy, better workmanship, increased production and greater freedom from accidents.

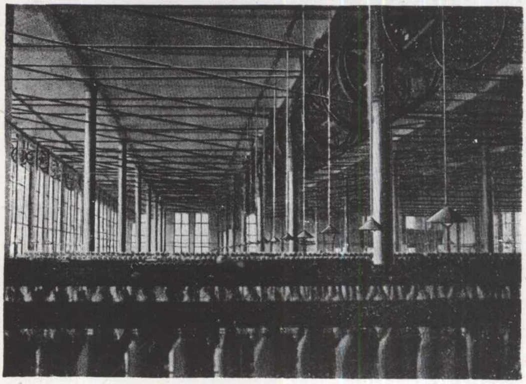


Fig. 19.
Lighting effect in a typical Ring Spinning Room.

Next in approximate order of merit in our list of advantages comes :—

SIMPLICITY. Simplicity is at the root of many great successes, and this property, both as regards erection, or installation and maintenance, has undoubtedly contributed much towards the success achieved by the English or Multiple System of Rope Driving.

Exact alignment and parallelism of shafts and pulleys, though desirable, is not essential to rope driving. The functioning of the drive does not depend upon these things, as it does in the case of belt drives, chain drives, etc.

Rope drives can thus be installed satisfactorily under conditions inimical to the other systems, and the cost of installation is considerably reduced in those instances where the conditions are equally suitable for all classes of drives.

Maintenance duty becomes the easiest of sinecures with a properly designed and installed rope drive. The reliability has already been fully demonstrated. The only attention required by a rope drive is of the most elementary kind and consists of a brief but regular inspection to see that none of the splices in the ropes are coming undone due either to accident or legitimate wear and tear. In some cases where the ropes run in unpleasant surroundings, that is to say, amongst grit, smoke, steam, acid, etc., it is advisable to give the ropes a sparing dose of rope-dressing at intervals in order to preserve them from the ill effects of these conditions.

Apart from this, rope drives require practically no attention, and in this respect compare very favourably with belts which consume prodigious quantities of special dressings and anti-slip compositions, or with chain and gear drives with their casings which often render accessibility very difficult, and their oil baths and automatic lubrication systems, correct functioning of which is generally a matter of vital importance.

From this we pass on to :—

ADAPTABILITY. For convenience in meeting awkward or extreme conditions, rope driving is generally admitted to be in a class of its own. The chief sphere in which this valuable property of rope drives is most commonly apparent is in angular drives, for a more technical discussion of which see our booklet on " Specimen Drives." By means of guide pulleys, suitably situated, rope drives can be arranged to run successfully with the driving and driven pulleys in any possible relative positions or planes, the only limit being distance.

Many gear, bevel and worm drives have been advantageously replaced by rope drives, as in the case illustrated by Fig. 20, where a bevel gear between two shafts at right angles in the same plane was replaced by the much more efficient and smoother running rope drive shown therein.

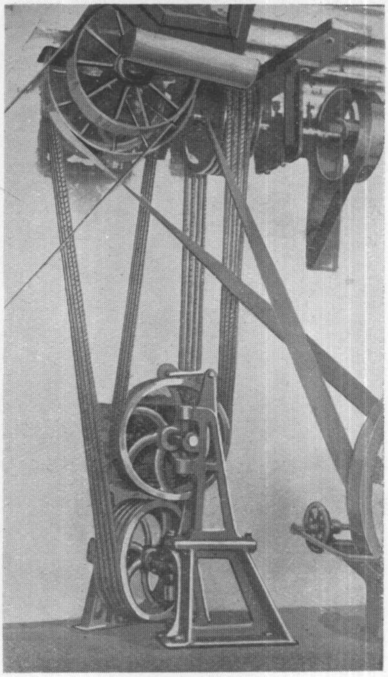


Fig. 20.
Right-angle Rope Drive.

A rope drive can and often has been arranged on the same principle when the shafts are at angles other than 90 degrees. Sometimes the shafts are not in the same plane, in which case a drive such as that shown in Fig. 21 can be installed.

Fig. 22 (see page 46) shows a very useful and ingenious drive to a disintegrator which requires two separate directions of rotation, one on a shaft and the other on a sleeve encompassing it. This is obtained and a tightening device is introduced whereby the stretch of the rope may be taken up. The drive shown in the illustration has run for over 15 years under very adverse conditions, yet has given absolutely no trouble.

Another interesting drive is shown in Fig. 23 (see page 47), and this very well illustrates the immense possibilities of rope driving in adapting itself to practically any conditions. Finally, Fig. 24 (see page 47), will give some idea of the many difficulties which a rope drive sometimes has to overcome. This drive was installed in a sawmill where the load was very erratic and fluctuated violently. It has to traverse nearly a right angle horizontally and pass from one plane to another, the direction of rotation had to be reversed and the whole drive had to be put out of the way beneath the floor. This was very successfully accomplished, and the drive runs in an absolutely satisfactory manner to-day. This is one of the instances previously mentioned, when the continuous system can be advantageously applied.

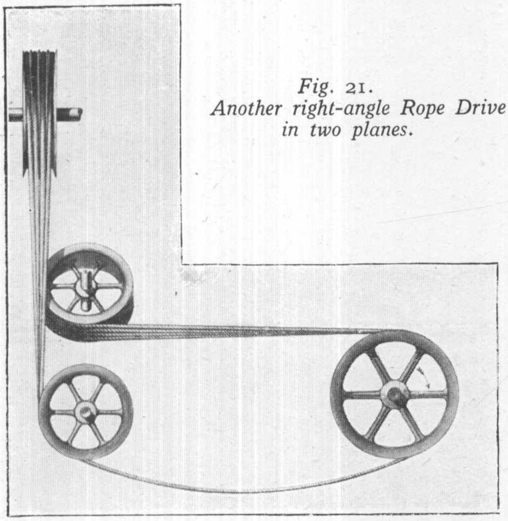


Fig. 21.
Another right-angle Rope Drive in two planes.

To summarise. Rope driving is not only more adaptable to uncongenial and trying conditions of atmosphere, environment, etc., but is applicable successfully to a great many combinations of mechanical conditions which render other drives impossible ; furthermore, rope driving generally is adaptable to wider limits of speed, power, temperature, humidity, etc., etc. than other systems.

We must now include in our list the very important quality of :—

RESILIENCE. This is possessed to a remarkably high degree by the Patent Inter-stranded Cotton Driving Rope, as is shown by the various experimental results and data published in our separate booklet on "Strength and Properties of Fibrous Ropes." The resilience of a good cotton rope may be taken as about three times that of a manilla rope of the same size and construction. This is of enormous utility in power transmission where the ultimate aim of the engineer is to get the power from prime mover to machine so that the variations in the former are not transmitted forwards, and any shocks in the

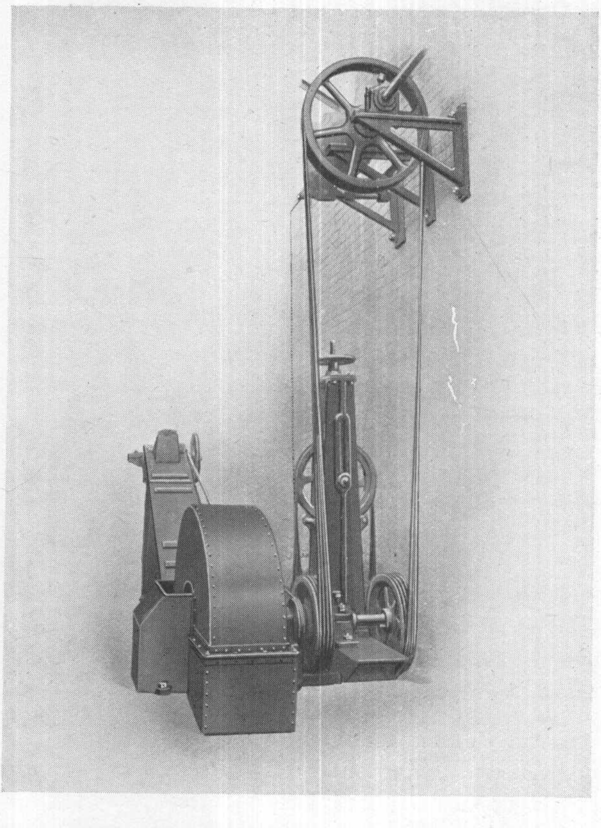


Fig. 22.
Disintegrator, Two-way Drive.

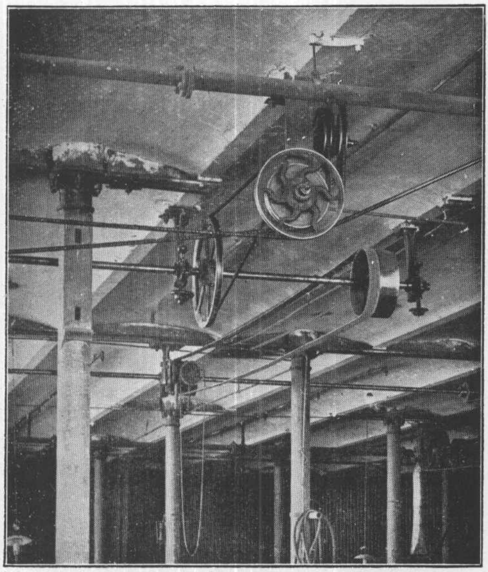


Fig. 23.
Single-rope Right-angle Drive.

latter do not recoil on to the former, both of which actions not only occur in many drives, but are sometimes actually intensified by the transmitting medium.

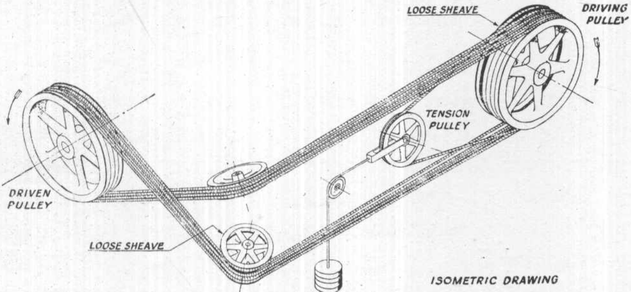


Fig. 24.
A very difficult drive on the continuous system.

The ability of a drive to absorb these undesirable and often harmful fluctuations of power, and to convert them into useful work, is extremely important. This property is termed resilience; "P.I." Cotton Driving Ropes possess more true resilience per unit weight per unit of power transmitted than any other medium of transmission.

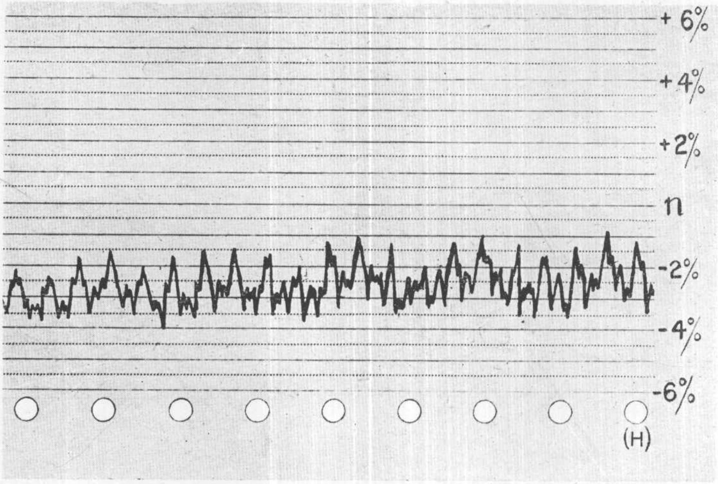


Fig. 25. (See Figs. 26 and 27.)
Tachograph diagram taken from line shaft in flax spinning room.

Line shaft 282 R.P.M. Coupling 10¼in. diameter. Pulley on tachograph 5¾in. diameter. No. 10 speed of paper. 6 per cent. springs.

The benefit to machinery, the improved rate of output, the reduced waste of power and the greater general reliability ensuing from the use of a resilient drive must recommend rope driving to every progressive power user. A striking example of the shock-absorbing properties of rope drives is illustrated by Figs. 25-27. These diagrams speak for themselves; they are representative of many other experiments carried out on this subject under actual working conditions. More extensive details can be found in our booklet on the "Driving of Spinning Frames" by those wishing to pursue this branch of enquiry further.

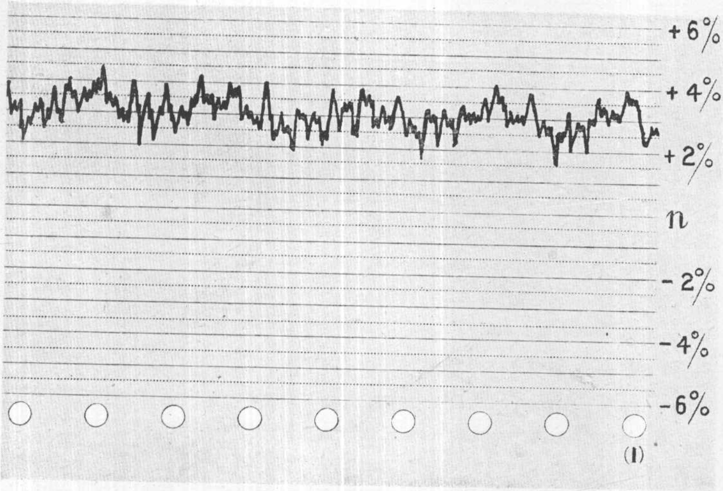


Fig. 26. Belt Drive.
Note that the amplitude of the speed vibrations is increased.
Tachograph record of belt driven tin roller of No. 66 flax spinning frame. Tin roller 10in. diameter. Tachograph pulley 9in. diameter. No. 10 speed of paper. 6 per cent. springs. Frame driven by line shaft recorded in Fig. 25.

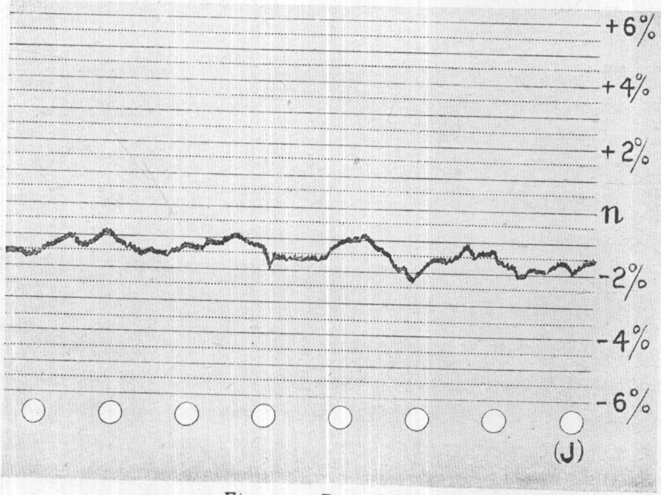


Fig. 27. Rope Drive.
Observe the beneficial damping effect of the rope drive.
Tachograph record of rope driven tin roller on No. 66 flax spinning frame. Tin roller 10in. diameter. Tachograph pulley 9in. diameter. No. 10 speed of paper. 6 per cent. springs.
The frame is driven by the line shaft recorded in Fig. 25.

After resilience we must consider as the next important virtue of rope driving :—

CLEANLINESS. This is of small commercial value in the general engineering and allied trades, but in certain industries it is of paramount importance. These are such as paper making, cotton spinning, flour milling, bleaching, dyemaking, and many other instances where a drive which deposits oil, dust or grit would be fatal.

It must be mentioned here that the immunity of rope driving in this particular respect is to some extent dependent upon the general arrangement and equipment of the drive. Thus, pulleys with unsuitable or unpolished grooves may produce a certain amount of " fluffing " from the ropes. Drives not in correct alignment may be liable to the same complaint if they are not properly designed. Bearings may splash their oil about or guide pulleys drop their grease promiscuously if of inferior design or construction.

This all goes to show that rope drives should not be allowed to develop in the casual fashion that has often characterised their installation in the past. The transmission of power by ropes is an engineer's job, not merely a rope maker's on the one hand, or the jobbing millwright's on the other. Permanent satisfaction can only be obtained from the specialist.

In conclusion, if a rope drive is a source of dirt, it can be taken for granted that something is wrong and that a proper remedy can be prescribed by an expert.

Amongst our list of advantages is also :—

NOISELESSNESS. This has been placed late in our list because the material benefits are not, perhaps, so immediately obvious as those already given. Many people consider this as of æsthetic interest only, or, perhaps, as a desirable incidental property with no economic significance.

The recent enquiry conducted into industrial fatigue showed that noise was an agency which contributed towards human fatigue to a startling extent. Trials are now being made in different parts of the country to eliminate or reduce the noise produced by various types of machinery.

The advantage of the rope drive over practically all other systems of transmission must be obvious to all who have seen rope drives running silently, and heard all the different grades and intensities of noise produced by other forms of transmission. In its least complex significance, noise means waste of energy which should be profitably employed.

Lastly, we include the valuable property : NO ELECTRICAL DISTURBANCES PRODUCED. By this we mean that, owing to the absolute precision of rope driving, no frictional electricity is generated by slip.

On the other hand, belt drives are very commonly subject to this complaint, and disastrous fires have been traced to this cause. Only two cases of electrical sparking produced from rope drives have come within our total experience, and in both instances the drives were of entirely incorrect design. The trouble was remedied quite easily.

If the reader has had the patience to persevere through the entire length of this procession of virtues claimed, we hope not without good reason, for rope driving, we would like to say in conclusion, lest there be any among our readers who have had bitter experience in the past of rope driving singularly devoid of many or all of these desirable properties, that the proper functioning of the system depends, as in all other things, upon its correct application.

We ourselves have had experience of drives woefully lacking in the ordinary decencies of mechanical transmission, let alone invested with the several advantages detailed in this chapter, but in all cases the trouble has been the inevitable result of abusing one or more of the fundamental principles.

If you consider the installation of a rope drive and wish to obtain the best results possible, there is only one thing to do—consult a specialist, preferably a reputable firm of manufacturers who specialise on the technical and engineering side of the question.

CHAPTER IV.

LIMITS OF ROPE DRIVING

THE first important limitation imposed upon any form of transmission is that of speed. During the last ten years this has attained a very wide significance due to the previously mentioned progress in high-speed engines and machinery.

Power is a product of force and velocity, therefore it naturally follows that if the velocity is increased the force that is necessary for a given horse-power may be decreased in inverse ratio. The effect of this is obvious in all kinds of machinery for developing, transmitting and utilising power. The dimensions of the particular apparatus may be safely reduced and considerable saving effected thereby. A drive which has the highest limits of velocity therefore possesses a great advantage over others which are subjected to closer limits in this respect.

Now, since practically all forms of transmission of general application depend fundamentally upon rotating pulleys or wheels, centrifugal stresses form an important proportion of those which have to be considered by the engineer. Centrifugal force is the outward or bursting component of the forces induced in any moving mass describing a curved or circular path. In the rims of pulleys, wheels, etc., this centrifugal force is resolved into centrifugal tension, which varies directly as the square of the velocity of the moving body. As the velocity increases at a certain rate, therefore, the resulting centrifugal stresses increase much more rapidly. The curve between velocity and centrifugal stress is as shown in Fig. 28. Obviously, a velocity will be reached with any revolving wheel where the centrifugal stresses alone are equal to the breaking strength of the material of which it is composed. This is what has occurred when pulleys burst.

In the past it was popularly supposed that driving ropes and belts, both of which are subject to the same centrifugal tension, could not be run at a higher speed than 4,800 F.P.M., because at higher speeds than this the centrifugal stress increased so rapidly as to reduce the margin remaining from the total stress permissible in the ropes available for transmitting power. Thus, the power must fall at speeds above this point, and it was not, according to this reasoning, economical to exceed this

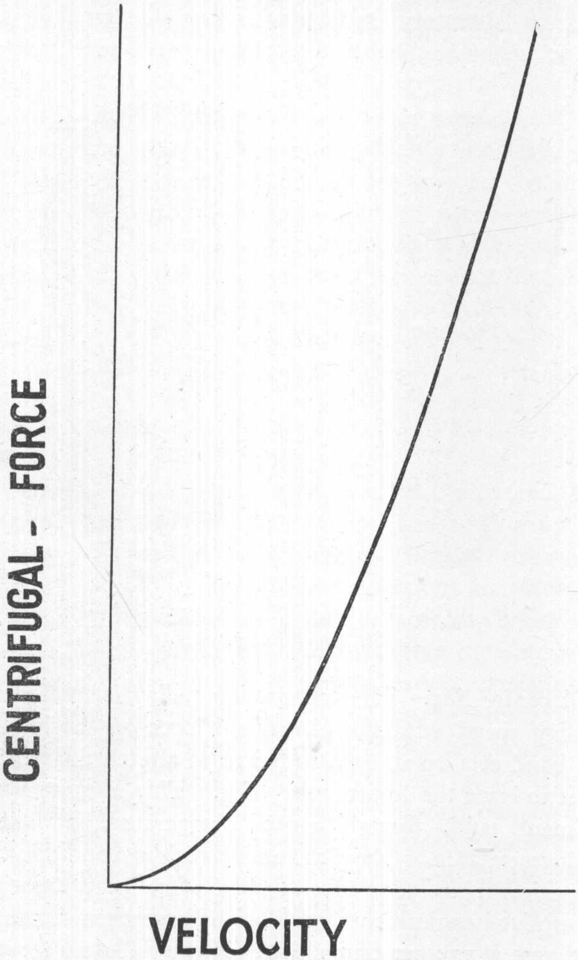


Fig. 28.
Showing variation of centrifugal stress with velocity.

arbitrary limit. This method of reasoning is fundamentally correct, but errs in the limit of stress permitted in the rope or belt.

The greatest misunderstanding has occurred in the popular conception of the effect of centrifugal tension. An old and well-known laboratory experiment is that illustrated by Figs. 29 and 30, where a rubber band is placed on two pulleys set on a vertical centre line. The top driving pulley is rotated at an increasing speed until the centrifugal force on the lower arc of the band sets up stresses sufficient to stretch the band and cause it to leave the lower pulley rim. This is quite a useful experiment, and, though much exaggerated, it faithfully reproduces what may take place under working conditions. But the experiment has led to considerable harm, because, like many other artificial experiments, conclusions have been drawn from it that were altogether unjustified. If the pulleys were placed on a horizontal centre line, the band would not fly away from either pulley. The effect of gravity has been overlooked.

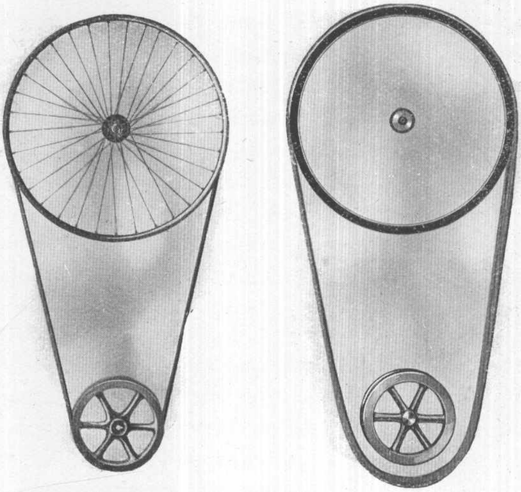


Fig. 29. *Fig.* 30.
Rubber Band Experiments.

In actual practice there is the possibility that the phenomenon produced in the experiment may be obtained, but only if the conditions are exactly the same, *i.e.*, if the centre-line of the drive were vertical. In no other position would it be possible, on account of the influence exerted by gravity.

Thus, we see that the centrifugal tension has the effect of increasing the stress in the ropes or in the belt. Provided the drive is designed with its pulleys of sufficient size to give a reasonable or economic life to the ropes, the stress can be allowed to increase well above the limits previously imposed.

Now, belt driving has been used longer than rope driving for the transmission of mechanical power, and the results obtained from this system, together with the inferences drawn therefrom, appear to have been erroneously applied to ropes. A belt cannot often be run satisfactorily at velocities exceeding about 3,500 F.P.M., although there are notable exceptions to this statement, exceptions, as a matter of fact, which serve to prove the general rule.

This inability to drive above a certain speed has been attributed to centrifugal force, whereas this is by no means the true explanation. What has been responsible for the limit imposed on belts has been air cushioning. Friction exists between air and a flat belt as between air and ropes or any other moving bodies. Consequently, the air surrounding the belt is caused to move in a current round with it and at a slightly lower velocity—until the belt enters the pulley when the path of the air underneath the belt is obstructed and its kinetic energy changed into pressure energy according to an elementary principle in mechanics. This pressure of air occurring between belt and pulley rim causes the belt to be forced up as shown in Fig. 31 (see page 56). A thin film of air is introduced between the belt and the rim for a greater distance, and the reduction in arc of contact resulting from this produces excessive slip. This phenomenon is termed " air cushioning," and has nothing whatever to do with centrifugal tension. With a rope drive, air cushioning scarcely exists and has no appreciable effect. The rope resting on the sides of the "vee" groove has a free air space underneath, and since the air is being drawn away as rapidly at the delivering side of the pulley as it is supplied to the point of entry, very little rise of pressure occurs under the rope.

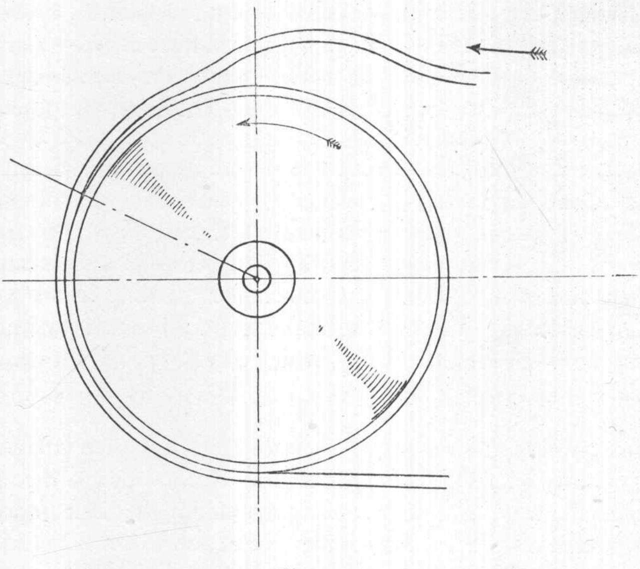


Fig. 31.
Belt Air Cushioning.

Belt pulleys are often made with holes drilled in their rims to afford relief for the compressed air, but this is only a partial remedy, and has incidental disadvantages.

We have thus seen how belt drives are limited in speed by air cushioning, whilst rope drives have been erroneously supposed subject to a similar but somewhat higher limit of speed due to centrifugal tension. The fallacy of this reasoning has been indicated, and there only remains to be seen if practice agrees with our contention.

A number of years ago, following out the convictions stated above, to test their accuracy we installed a number of high-speed drives.

One was installed at a Lancashire Spinning Mill with a rope velocity of 7,033 F.P.M. obtained from a 28′ 0″ flywheel pulley making 80 R.P.M. Fifteen ropes 1⅝″ diameter convey the entire load of card room and five spinning rooms. The card room is driven by three ropes and takes 286 H.P., or say 95 H.P. per rope. Now, at 4,800 F.P.M. an 1⅝″ rope should transmit about 43 H.P. according to the usual standards, so that in this case, far from losing power above the so-called critical speed we have considerably increased the power transmitted.

It is useful to compare these drives with those at another Cotton Mill, where 1⅝″ diameter ropes are used under somewhat similar conditions; the rope velocity in this case is 4,396 F.P.M., and 24 ropes are used to drive the whole mill, which takes, if anything, just a little less power than the former one described. Thus, by reducing the speed, 84 per cent. more rope is required for approximately the same power.

The modified centrifugal tension theory was given a further thorough test at a Belgian Rolling Mill, of which the conditions are as follows :—

				Weight
Driving Pulley	10′ 5″	diameter,	268 R.P.M...	12 tons
Driven „	5′ 2″	„	540 „ ..	6 „

Rope Velocity 8,750 *F.P.M.*

Twelve ropes 1⅞″ diameter.

Load : Rising to over 1,500 H.P. peak load, or 125 *H.P. per rope.*

With Patent Inter-stranded Cotton Driving Rope this drive yields an average rope life of two years continuous running. With hemp ropes, however, never more than two months' life was obtained, and in this short period they required tightening several times.

In both of these high-speed drives mentioned the pulleys were specially built up of steel and wrought iron in order to withstand the high centrifugal stresses set up in the rim. This is the principal danger in the case of a rope drive; the ropes themselves are quite safe within known limits, the metal pulleys reaching their limit of safety first.

This is due to the fact that centrifugal force also varies directly as the density of the material. From this it follows that the limits of speed of the chain drives, gear drives, steel belt drives, etc., are much lower than with a rope drive, and the advantage of greater mechanical strength possessed by the former systems of driving is thus counterbalanced by their correspondingly greater densities.

Modern developments of high-speed rope driving have largely followed the lines of high revolution speeds. This is of great importance also because, all things being the same, the cost of electro-motors varies inversely with their speeds of revolution. Formerly, a belt has been supposed to hold the advantage in this respect ; pulleys about four or six inches diameter with single-thickness belts being quite common. It may come as a surprise to some people to learn that similar conditions can be met satisfactorily by rope driving. Not only can the rope drive be applied to these conditions, but it can excel in this particular sphere, the amount of slip being negligible in comparison with belt drives.

In this direction we will quote an actual example, which is illustrated in Fig. 32. This drive is to a wood planing machine, the drive being by a single rope, ½″ diameter, from an 18″ diameter pulley on a countershaft running at 1,400 R.P.M. on to a 6¼″ pulley on the cutter block shaft of the machine designed to run at 3,950 R.P.M. The average power taken by the machine is 4-5 horse power. Extensive speed tests were taken on this machine, which gave an average revolution speed of 3,960 R.P.M., running light. The average speed of the driven pulley whilst taking full cut on baulks of timber of various kinds, 12″ wide, under constant conditions of feed, etc., as in general

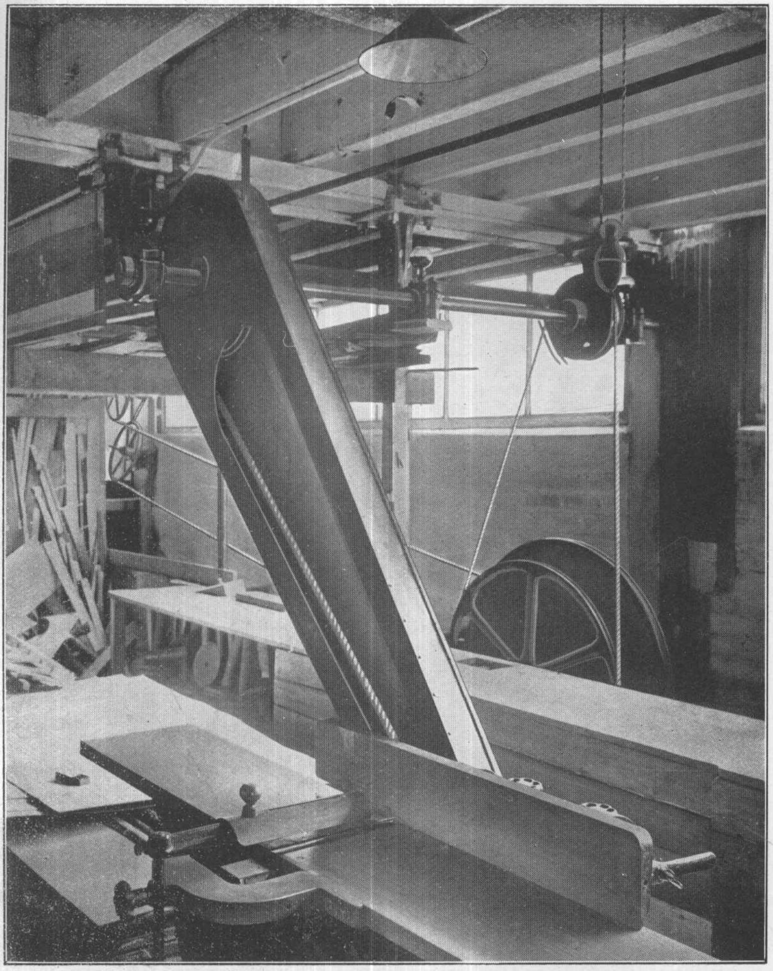


Fig. 32.
12in. Wood Planer at 3,950 R.P.M. driven by one ½in. rope at 6,480 feet per minute.

practice, was 3,931 R.P.M., showing a total loss of only 29 R.P.M. on full speed from no load to full load, or 0·74 per cent., including extra creep, slip and possible slowing up of countershaft.

The rope speed on this drive is 6,480 F.P.M. Tests on belt driven machines of similar design and capacity showed that from five to eight per cent. loss of speed invariably occurred under similar conditions.

We have thus actual working examples of rope drives satisfactorily performing their duty at over 8,000 F.P.M. and on pulleys running at almost 4,000 R.P.M., neither of which values are necessarily limits for the system, although beyond the reach of belt driving and other drives for all practical and economic purposes.

Passing on from velocity, the next important limit to be considered is that of dimensions, which, in the case of drives, is principally centre distance. There is no lower limit to the centre distance of a rope drive, except that this obviously cannot be less than half the sum of the pulley diameters plus a sufficient clearance between their rims. Rope drives have quite often been installed with their driving and driven pulleys almost touching. In Fig. 33 is shown a large drive of this kind, where there is only 8″ between the pulley rims, the drive transmitting 360 H.P. This drive has been in commission for over 30 years, and was originally installed to replace an unsatisfactory gear drive. Another instance can be quoted of a rolling mill, where spur gearing, belt and chain drives had all been tried, but found unable to meet the peculiar demands of the situation. Rope pulleys, 4′ 2″ diameter, were installed at a centre distance of 6′ 0″, having only 20″ clearance between rims, and the drive of seven 1¾″ ropes so introduced has functioned satisfactorily ever since. The average load on this drive is 200 H.P., the peak loads being considerably higher than this.

It is, of course, necessary for allowances to be made in the rate of stressing in the ropes when such small centre distances are

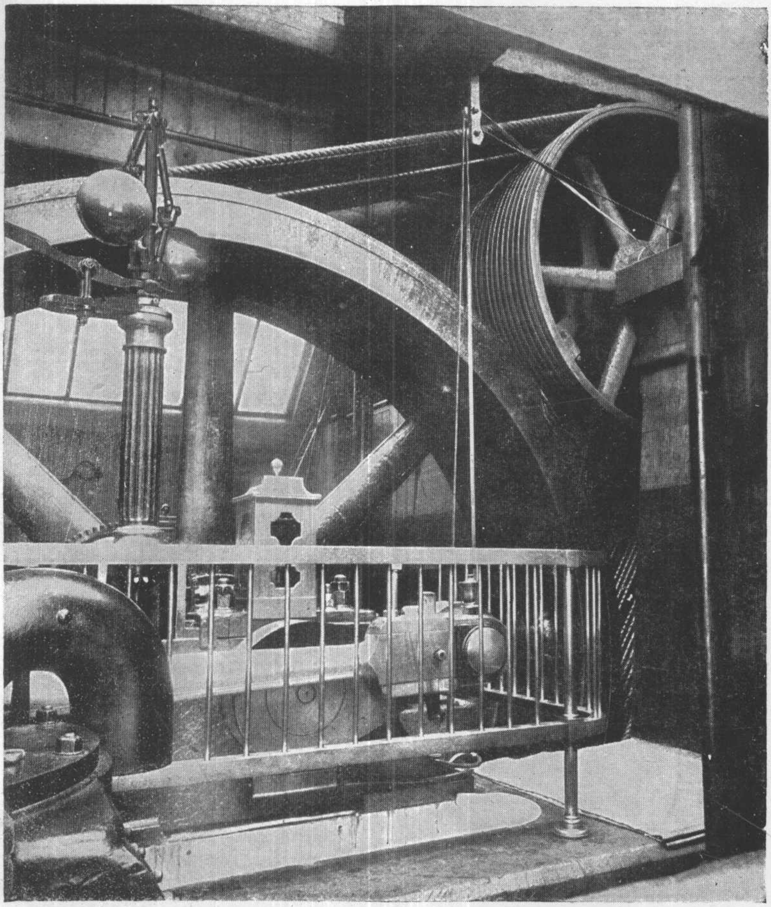


Fig. 33.
Short Centre Drive transmitting 360 H.P.
There is only a distance of 8in. between pulley rims.

utilised. In the main, it is desirable never to have a centre distance of less than twice the mean pulley diameter. This is a fairly good empirical rule, and it should be borne in mind always that the accurate determination of the number of ropes necessary for a very short centre drive is a much more complex affair.

The following allowances, however, are on the safe side for all ordinary conditions, and should be followed in all cases where expert consideration cannot immediately be obtained :—

TABLE I.

Centre distance less than	Extra number of ropes necessary
D1+D2	20 per cent.
0·8 (D1+D2)	35 ,,
0·7 (D1+D2)	60 ,,
0·6 (D1+D2)	100 ,,

Longer centre distances are possible with rope driving than with any other type of mechanical drive. Centre distances up to 80 feet are comparatively common on main drives to cotton mills. One drive has been installed with a centre distance of 156 feet without any supporting pulleys or intermediate assistance of any kind. When the slack side of a drive is uppermost, the centre distance is limited in order that the sagging ropes will never fall low enough to rub against the tight side.

The pulley diameters obviously determine the maximum centre distance permissible with this kind of drive. Where the slack side is underneath, however, the only limit imposed depends upon the amount of clearance allowed under the middle of the span. At least five per cent., and preferably seven and a half per cent., of the centre distance should be allowed at this point.

Whenever possible, however, it is best to keep the centre distance of a drive down to a maximum of about fifty feet if horizontal, and about seventy feet if inclined moderately, because experience show that a very long drive does not last quite so long as one with a moderate centre distance.

The reason for this is probably that rope wear, depending upon tension, is increased by the greater tensions resulting from longer spans.

It is therefore advisable to split very long drives up by means of intermediate countershafts, unequal centre distances being chosen for the component drives. This is very much better practice than the use of a number of supporting pulleys under the slack side, every one of which contributes towards rope wear and loss of efficiency as much as, if not more than, a driving or driven pulley.

To the widths of rope drives there are no limits except those of convenience in providing a rope race. Generally, the largest amount of power necessary may be transmitted without attaining any excessive proportions in width. Single pulleys sometimes cannot be constructed, in which cases similar pulleys are bolted together.

The inclination of drives is the next factor, of which the limitations can be considered. The most extreme case of this kind is, of course, the vertical drive. For this condition a rope drive is more suitable than a belt on account of the greater ratio of tight side to slack side tension permissible without slip.

It has previously been mentioned that the power transmitting capacity of a rope drive so far as the adhesion between ropes and pulleys is concerned is increased with the back tension. This back tension is the tension induced in the slack span of the rope due to its own weight, and since the rope hangs in the form of a catenary curve, the tension can be calculated from the equation to this curve (see booklet on " Theory ").

For practical purposes, however, it is generally sufficiently accurate to assume the curve to be a parabola, and to obtain the tension from the much simpler equation to this curve.

The tension in a rope span varies approximately as the square of the span, and inversely as the dip or sag. Also, the tension is reduced as the rope is inclined, until a minimum value is obtained when the rope is vertical, when it is then only the weight of the rope itself.

From this it follows that as a drive is more inclined its back tension is reduced and the adhesion between rope and pulley decreased. Allowances must therefore be made, and for general conditions these may be safely taken to be as follows :—

TABLE II.

Inclination of drive centre-line with horizontal	Minimum extra number of ropes necessary
Up to 30°	None
30° to 45°	10 per cent.
45° to 60°	15 ,,
60° to 75°	25 ,,
75° to 90°	50 ,,

A highly inclined drive will therefore be somewhat more expensive in capital cost than a horizontal one, but this is the only disadvantage. For this reason it is advisable to avoid highly inclined drives whenever conveniently possible.

If essential, vertical drives can be installed to run with perfect satisfaction.

When the centre distance is very great it may be advisable to instal the continuous system, as in the instance quoted in Figs. 8 to 12, pages 23-28, but it is impossible to lay down as a general rule at what distance this recommendation should be followed. The simplest arrangement of the vertical continuous drive is shown diagramatically in Fig. 34.

A highly inclined or vertical continuous drive does not require any extra ropes as compared with an otherwise similar but horizontal drive.

Generally speaking, there are no limits to the power which may be transmitted by a rope drive. There has never yet been an instance where it was impossible to instal a rope drive on account of the amount of power to be transmitted, whether large or small.

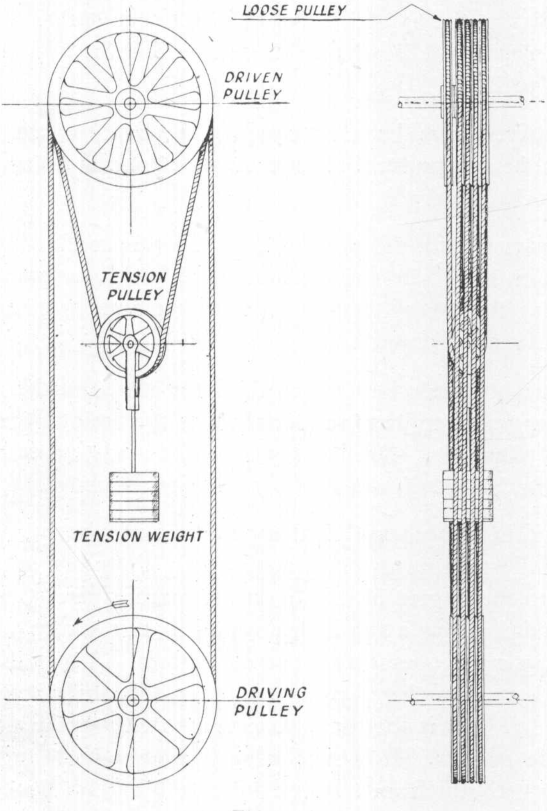


Fig. 34.
Vertical Continuous Drive.

In the U.S.A. rope drives have been erected to drive rolling mills absorbing 10,000 H.P. The illustration shown in Fig. 5 of a South Wales rolling mill is of a drive which has to carry loads of up to 4,000 H.P.

At the other end of the scale, the general applicability of rope driving is equally manifest. Drives have been installed on sewing machines to transmit less than $\frac{1}{8}$ horse power, on motor car dynamos taking 0·25 horse power, on cream separators taking less than 1 horse power, on cooling fans for petrol engines taking less than $\frac{1}{3}$ horse power, and there is the smallest of all drives, the spindle drive of the textile spinning frame, which may rotate a wharve at 10,000 R.P.M. and transmit only 1/50 H.P.

Rope drives have been successfully applied to transmit all magnitudes of power between these extremes of 10,000 to 0·02 horse power.

Rope diameters for the great bulk of drives are confined between the limits of $\frac{3}{4}''$ and $1\frac{3}{4}''$ diameter, although occasion often arises for the use of driving ropes as small as $\frac{1}{4}''$ diameter or as large as $2\frac{1}{2}''$ diameter.

They are not made larger than the latter size, and the modern tendency seems to be to render obsolete the use of larger ropes than 2″ diameter. Driving ropes can be made on exactly the same principle $\frac{1}{8}''$ diameter as any other of the above sizes.

It has already been said that rope drives can be run without their pulleys being in exact alignment; there are, of course, limits to the degree of misalignment permissible. Generally, the maximum angle at which a rope will run on to a pulley with special grooves is about seven degrees. A rope drive can be made to run, therefore, on pulleys whose shafts are 14° out of parallel. This is about the extreme case without the assistance of guide pulleys. It is not advisable to have a rope drive running so much out of alignment if it can be avoided, because, even with specially designed grooves, the amount of rope wear is rather high, and it is consequently more economical to utilise guide pulleys.

A limit of 6° should be imposed upon the non-parallelism of the shafts in all other than very exceptional circumstances. With this angle the drive can be arranged to function quite well. The figures given above are dependent upon the conditions; in examples where the centre distances are short or the pulley diameters large in comparison, the limits must be reduced.

The theoretically correct method of arrangement is shown in Fig. 35, where the small pulley on the left is driving and that on the right the driven. In practice, especially when the rope velocity is high, a slight modification in the relative positions of the pulleys is necessary on account of the fact that the inertia of the ropes tends to make them follow slightly curved paths. The best positions can only be obtained by trial, so that long keyways should be cut in the shafts to permit slight lateral adjustment.

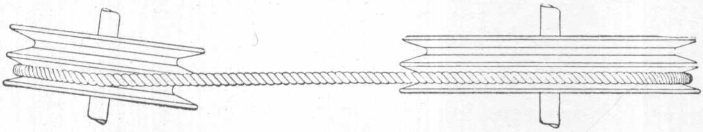


Fig. 35.
Non Parallel Shafts.

If guide pulleys can be used, there are no limits to the angles which may be driven (see our booklet on " Specimen Drives ").

Drives have to encounter and satisfactorily withstand wide ranges of temperature and humidity in their application to various industries. Sometimes they may even be fully exposed to climatic variations. Rope drives are particularly adaptable to these conditions, a fact which is taken advantage of in an increasing degree by power users of all denominations.

Considering humidity, no better illustration of the property of rope drives to withstand all ill effects of this can be given than the cotton and the paper-making industries. In the former case artificial humidification is necessary in the spinning rooms, where ropes are so extensively and successfully employed. In paper mills ropes are very frequently used on or beside the huge paper-making machines, which necessarily emit large volumes of steam. The percentage of humidity in these places is very high.

Again, ropes are extensively used in tanneries, in situations where a great deal of water may be splashed on to the ropes.

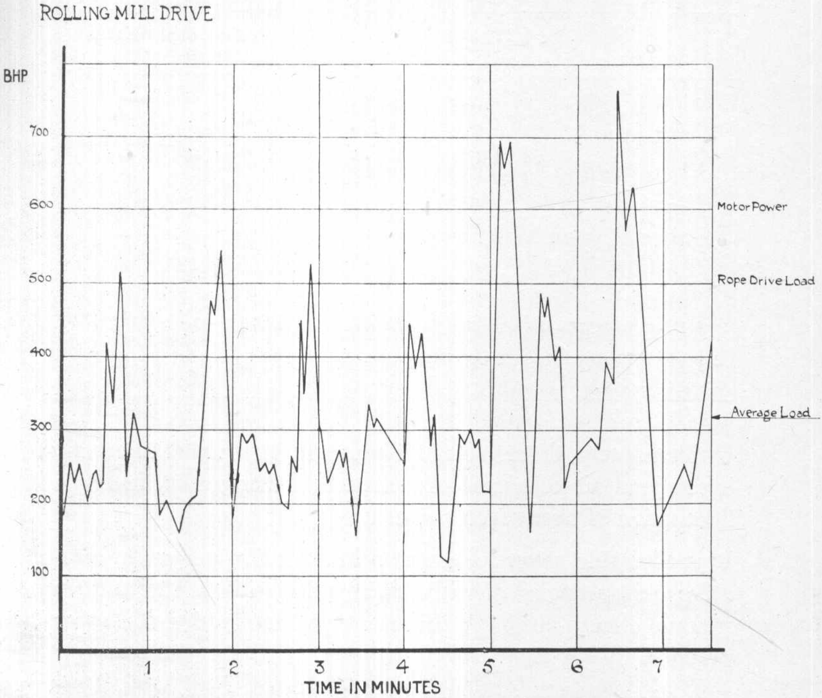
A cotton rope, if soaked in water by complete and prolonged immersion, has a saturation point of 28 per cent. of its own weight, and under these conditions experiments show that the shrinkage of a **PATENT INTER-STRANDED COTTON DRIVING ROPE** has an average value of 2·9 per cent., whilst the intensity of stress set up by this shrinkage is less than 600 lbs. per square inch of rope section. Now, a dressed rope never absorbs more than five per cent. of moisture under the most extreme conditions of atmospheric humidity experienced in this country, so that it will be readily understood why rope drives are not adversely affected. It is always advisable to keep the ropes which run in a wet atmosphere well dressed (see chapter on " Maintenance ").

Frequent treatment with a suitable dressing will also prevent any ill effects resulting from temperatures as high as 200°F. Ropes have to endure such temperatures continually in some rolling mill and similar drives.

Rope drives are very frequently used where the load violently fluctuates in magnitude. Accurate readings of the load variations actually developed in practice are very difficult to obtain except when the motive power is electrical. The typical load-time curve of a sheet rolling mill is shown in Fig. 36. The design in this instance is representative of sound practice in this class of work. It will be observed that whilst the average load is only 330 horse power, the " peak loads " attain a magnitude of 700 H.P. and even 750 H.P., or two and a quarter times the average load. Furthermore, they are of appreciable duration, lasting in some cases as long as 0·4 minutes. It will be apparent how dangerous it would be to attach significance to the "average load " alone. The motor on this drive had a capacity up to 600 H.P., whilst the drive was nominally capable of transmitting up to 500 H.P.

There is no practical limit to the magnitude of load fluctuations which may be borne by a rope drive, but it is economically soundest policy to limit the peak loads to a maximum value of three times the " time average " by means of a flywheel.

The capacity of the rope drive would then depend upon the periodicity of the peak loads ; generally, the drive should be designed to transmit normally up to 75 per cent. of the maximum peak. The subject is too technical to permit a more detailed reference here, our point being to show that no matter how severe the conditions, these can be encountered by the rope drive provided it has been correctly designed in accordance with the known conditions. Further reference is made in the booklet on the " Theory of Rope Drives."



POWER CURVE OF MOTOR DRIVEN SHEET MILL

Fig. 36.

Typical Load-time curve for Rolling Mills.

Cyclical speed variations often occur in prime movers and various types of machinery in common use. Table No. III. gives a list of average values for the fluctuations in speed from the mean of different types of machines.

TABLE III.

Type of Machine	Cyclical speed variation from mean
Pumps, Shearing and Pumping Machines	4 to 5 per cent.
Flour Milling Machinery (average)	3 to 4 ,,
Looms	3 to 5 ,,
Paper Making Machinery ..	2·5 ,,
Machine Tools	2·5 to 3 ,,
Spinning Machinery	1·0 to 2 ,,
Electrical Motors and Generators	·75 ,,
Belt Driven Line Shafting (average)	3 to 5 ,,

Unfortunately, these values are sometimes exceeded in practice, high-speed air-compressors sometimes having a cyclical speed fluctuation of over seven per cent.

It is advisable never to exceed a limit of five per cent., a rope drive being capable of withstanding this without showing very serious effect, although this is not recommended for general practice.

For prime-movers a smaller limit should be imposed, otherwise dangerous rope vibrations may be set up, causing the ropes to be thrown off the pulleys. A maximum cyclical speed variation here of four per cent. is the limit for satisfactory driving.

If loads or driving impulses contain greater cyclical speed variations than the limits specified above, they should be reduced to within the necessary bounds by means of flywheels, and it should be remembered in all cases that the steadier the drive the longer the rope life.

The total stress in a cotton driving rope transmitting its normal load is a factor which is important only from the point of view of wear. No limits are necessary on the score of safety, since the stresses actually developed in practice never can approach near to the ultimate strength of the rope. In Table No. IV. are given the guaranteed breaking strengths of each size of Kenyon's PATENT INTER-STRANDED COTTON DRIVING ROPE :—

TABLE IV.

Diameter of Rope	Guaranteed Breaking Strength in lbs.
$\frac{1}{2}''$	2,600
$\frac{5}{8}''$	3,400
$\frac{3}{4}''$	4,200
$\frac{7}{8}''$	5,200
$1''$	6,400
$1\frac{1}{8}''$	7,700
$1\frac{1}{4}''$	9,400
$1\frac{3}{8}''$	12,000
$1\frac{1}{2}''$	15,000
$1\frac{5}{8}''$	18,000
$1\frac{3}{4}''$	22,000
$1\frac{7}{8}''$	25,000
$2''$	28,500
$2\frac{1}{4}''$	35,000
$2\frac{1}{2}''$	40,000

Now let us consider a concrete example. An $1\frac{3}{4}''$ diameter rope running at 5,000 F.P.M. on a properly designed drive will transmit 50 H.P., whilst its weight per foot is approximately 1 lb.

The static back tension with a span of 30′ 0″ and a sag of three per cent. at the centre would be 125 lbs.

The centrifugal tension would be 217 lbs., so that the kinetic back tension=342 lbs. In order to transmit 50 H.P. the total tight-side kinetic tension must therefore be 672 lbs., because :—

$$\frac{(672-342)\quad 5{,}000}{33{,}000} = 50$$

The breaking strength of a $1\frac{3}{4}''$ diameter rope is found from Table IV. to be 22,000 lbs., so that the maximum working stress in the rope is just less than one-thirtieth of the total strength of the rope, the ratio being 1 : 30·6 precisely.

With 40° grooves in the pulleys, the maximum permissible tight-side tension without any slip is approximately 830 lbs. This is interesting to note because it means that at the given speed the rope will actually have a 25 per cent. overload capacity on its slipping point in the groove—the most important determining factor.

The stresses in the rope can be increased considerably by using some device to increase the grip of the pulleys on the rope. In slow-speed driving the stresses have been as high as one-eighth of the ultimate strength of the rope in some special instances. The reason why this has been permissible has been that with a very low speed wear has been decreased proportionately. Usually, it is not wise to allow the stresses in a rope on a normal rope drive to exceed one-twentieth of the ultimate strength of the rope, the slipping point being never, of course, exceeded.

The exigencies of any special or extraordinary conditions should be referred to the expert.

We can assure our readers that the values and limits specified in this chapter are all based upon very sound practice and experience ; if adhered to they should lead to satisfaction.

Since, however, we are always prepared to consider any driving scheme "in extenso," we cannot accept responsibility for a drive, even if following our recommendations set forth in this book, unless the particulars of the entire drive and its conditions are submitted to us beforehand.

CHAPTER V.

APPLICATION OF ROPE DRIVES

THERE is scarcely a single industry at the present time which does not utilise a rope drive in some place or other. This chapter has been included, however, not with any idea of attempting to prove or even demonstrate the truth of this statement, but merely in order to furnish the reader with a glimpse of actual modern practice: to provide a few concrete examples drawn from different branches of industry which will give substance to many of the claims made in the earlier part of the book.

First of all, however, we will include an alphabetical list of various classes of industry and manufactures in which we ourselves have installed rope drives during the past few years. This is given below, and does not by any means represent the complete sphere of activity of rope driving.

LIST OF DIFFERENT INDUSTRIES IN WHICH WE HAVE INSTALLED ROPE DRIVES DURING THE LAST FEW YEARS

AUTOMOBILE ENGINEERS.
AEROPLANE BUILDERS.
AUTOCLAVE MAKERS.

BREWERIES.
BAG WORKS.
BOOT AND SHOE MANUFACTURERS.
BOOT POLISH MAKERS.
BOILER WORKS.
BOTTLE FACTORIES.
BUCKLE MAKERS.
BLEACHING WORKS.
BUILDERS.
BRAID MANUFACTURERS.
BRICK WORKS.
BURNER MAKERS.

CANDLE MAKERS.
COTTON FACTORIES.
CARPET FACTORIES.
COLLIERIES.
COAL MERCHANTS.
CREAMERIES.
CHALK PITS.
CEMENT WORKS.
CARBONISING WORKS.
CONFECTIONERY MAKERS.
CORN MILLERS.
CANVAS FACTORIES.
CHEMICAL WORKS.

DYE WORKS.
DOUBLERS (TEXTILE).
DROP STAMPERS.
DOCKYARDS.
DIESEL ENGINE MAKERS.
DISINTEGRATOR MAKERS.

ENGINE MAKERS.
ELECTRICAL ENGINEERS.
EXTRACTION PUMP MAKERS.

FLAX MILLS.
FLOUR MILLS.
FERTILIZER MANUFACTURERS.
FAN MAKERS.
FIREBRICK MAKERS.
FLEECE SCOURING.
FILE MAKERS.
FOUNDERS.

GENERATING STATIONS.
GRANITE QUARRIES.
GROCERY MERCHANTS.
GAS WORKS.
GAS ENGINE MAKERS.
GRINDING WHEEL MAKERS.
GALVANIZING WORKS.

HIDE AND SKIN MERCHANTS.
HOSIERY MANUFACTURERS.
HOLLOWARE MAKERS.
HEMP SPINNERS.
HAULAGE GEAR MAKERS.

IRON WORKS.
IRONMONGERS.
ICE FACTORIES.

JUTE MILLS.
JAM FACTORIES.

LEATHER TANNERIES.
LIME WORKS.
LINEN MILLS
LOCOMOTIVE WORKS.
LAUNDRIES.

MALT WORKS.
MULE MAKERS.
MOTOR ENGINEERS.
MARGARINE FACTORIES.
MINES.

NEEDLE MAKERS.

OMNIBUSES.
OAT MILLS.
OIL, SEED AND CAKE MILLS.
OIL REFINERIES.
ORE CRUSHING MILLS.
OIL ENGINE MAKERS.

PIRN WINDER MAKERS.
PIANO MANUFACTURERS.
PUMPING STATIONS.
PAPER MILLS.
PRINTING WORKS.
PAINT MANUFACTURERS.
POTTERS.
PEN MAKERS.
PILE DRIVER CONSTRUCTORS.

QUARRIES.

ROLLING MILLS.
RICE MILLS.
RUBBER WORKS.
REED AND HEALD MAKERS.
REFRIGERATION WORKS.

SEWING MACHINES.
SHIRT MANUFACTURERS.
SHIPYARDS.
STATIONERY OFFICES.
SHEET AND METAL WORKS.
SUGAR REFINERS.
SAW MILLS.
SILK MILLS.
SOAP WORKS.
SPELTER WORKS.
SPRING MAKERS.

TURBINE MAKERS.
TOBACCO MANUFACTURERS.
TINPLATE MAKERS.
TILE MAKERS.
TOFFEE MAKERS.
TANNERIES.
TIMBER WORKS.
TOW SPINNERS.
TURNIP CUTTER MAKERS.
TANK MAKERS.

UNIFLOW ENGINE MAKERS.

WORSTED SPINNERS.
WATER SUPPLY BOARDS.
WEBBING MANUFACTURERS.
WAGON BUILDERS.
WOOLLEN MANUFACTURERS.
WIRELESS STATIONS.

YARN MERCHANTS.

ZINC MINES.

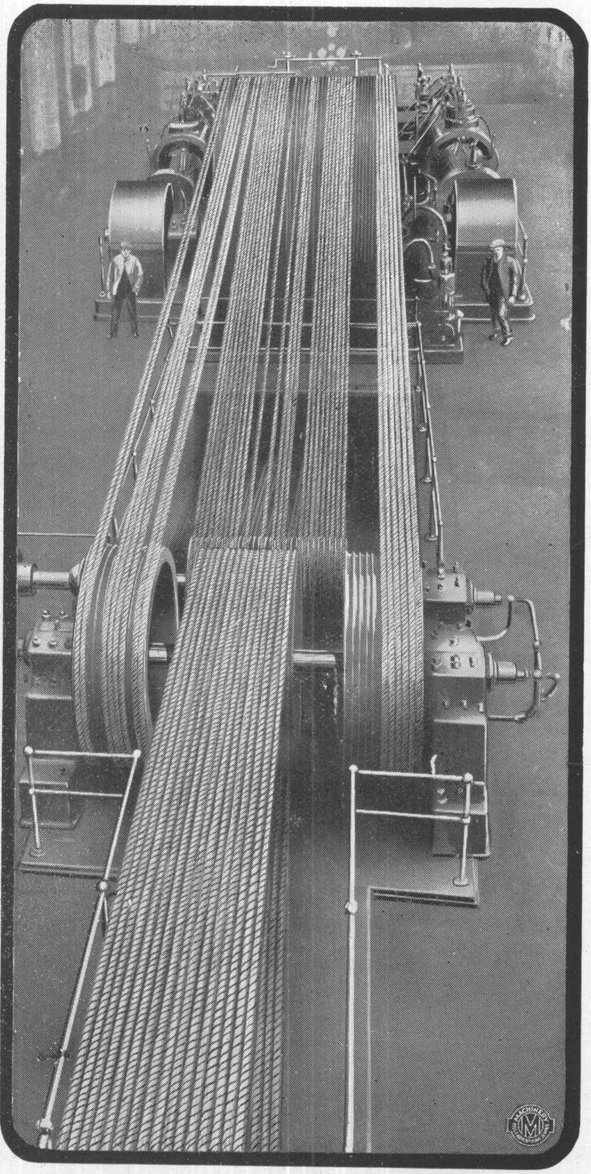


Fig. 37.
Large Modern Rolling Mill Drive.

One of the most important directions in which rope driving has been applied with overwhelming success is that of rolling-mill driving. Rolling mills of all kinds : wire, bar, strip and sheet, electrically and steam driven.

Fig. 37 (see page 75) affords a good bird's eye view of a modern and well planned example of this class of drive. A specimen taken from the other end of the scale is shown in Fig. 38 opposite. This drive is subject to very uncongenial conditions so far as variations of temperature and humidity are concerned. The severity of the conditions can be well judged from the photograph.

The driving of sheet mills is exemplified by the typical case shown in Fig. 39 (see page 78). This is a drive of twenty-four 2″ diameter ropes, which transmit the power to 18 pairs of cold rolls similar to those shown in Fig. 40 (see page 79). These drives have been running since 1913, and the foreman said " They look like lasting for ever."

Another example of the wide applicability of rope driving is given by Figs. 41 and 42 (see pages 80-81). The former of these illustrations shows the general view of a heavy rolling mill drive ; the latter view showing the rope drive itself in more detail. It will be noticed that the drive is in two sections, one an ordinary open drive and one a crossed rope drive. By the aid of a suitable clutch, this arrangement enables the rolls to be reversed for the various passes. Each drive transmits an average of 500 H.P., and there are three identical sets in the same mill.

Fig. 43 (see page 82) shows the engine room of a large Sheffield wire drawing mill ; the load on the main drive here fluctuates around 1,500 B.H.P. The ropes give excellent service, the last set having run since 1917 and are in perfect condition to-day.

Lastly, among rolling mills we will quote one with a rope velocity of 6,000 F.P.M. This is shown in Figs. 44 and 45 (see pages 83-84), and the ropes have now run over eight years, often with continuous stretches of night and day work, without a single break due to rope failure or trouble of any kind. Notice that the ropes have been provided with a wooden guard, as shown in

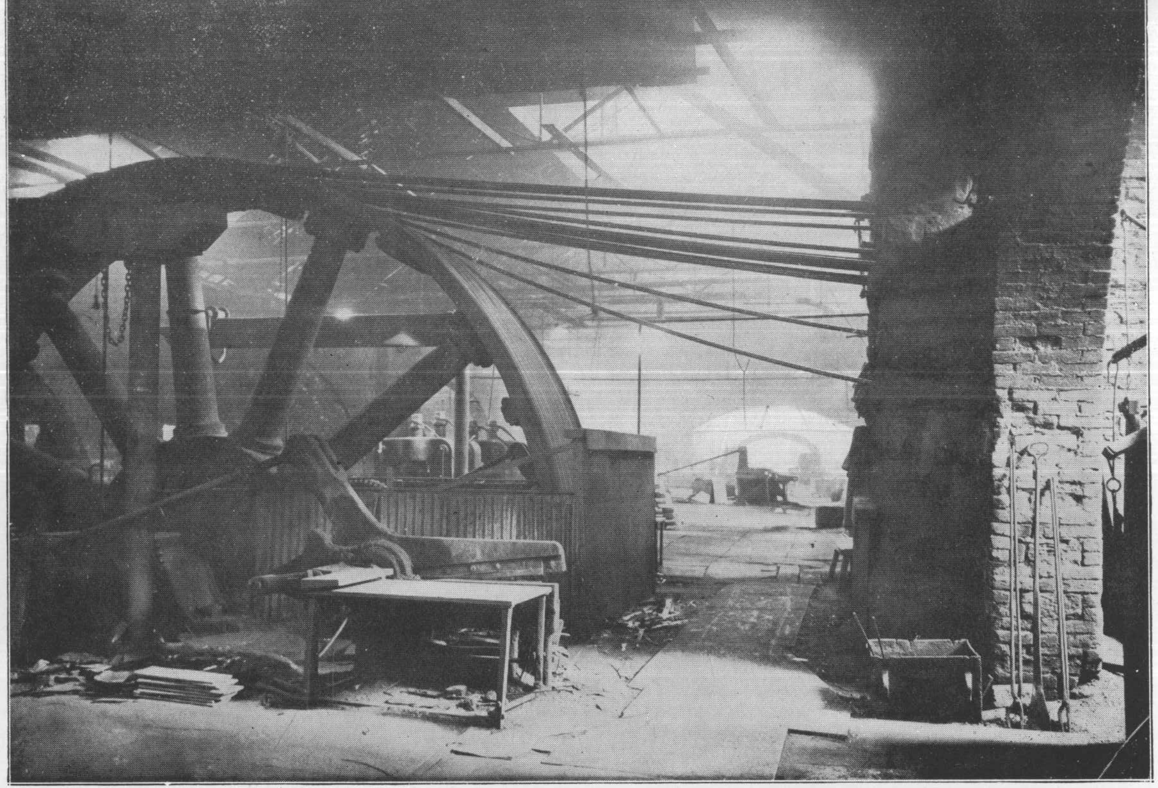


Fig. 38. Old Rolling Mill Drive, under difficult conditions.

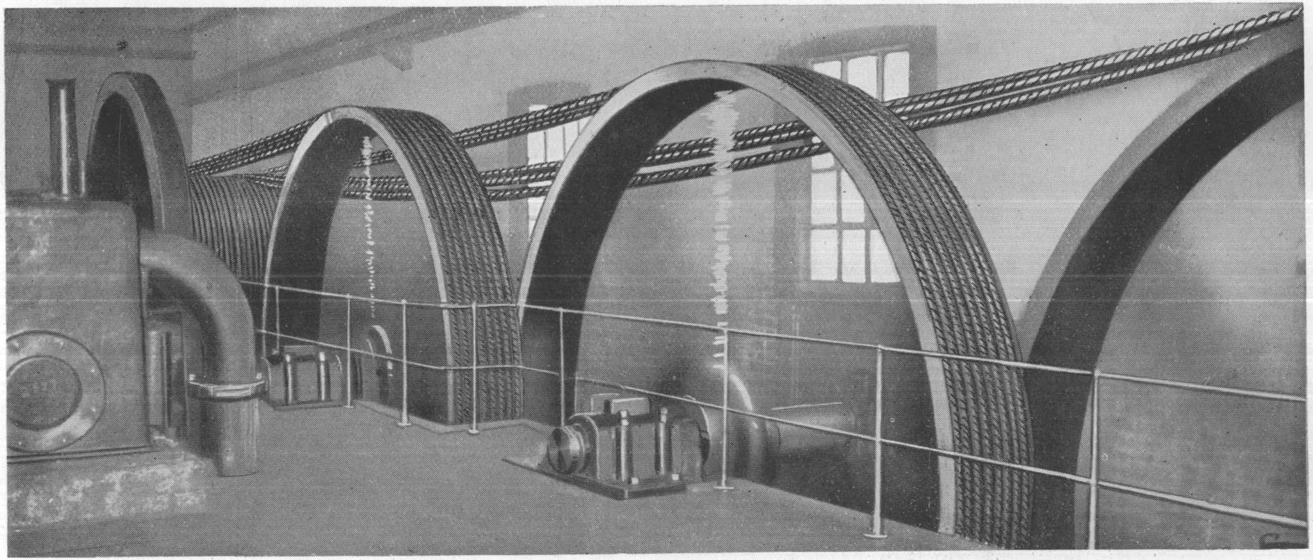


Fig. 39
Sheet Mill Drives in Tinplate Works.

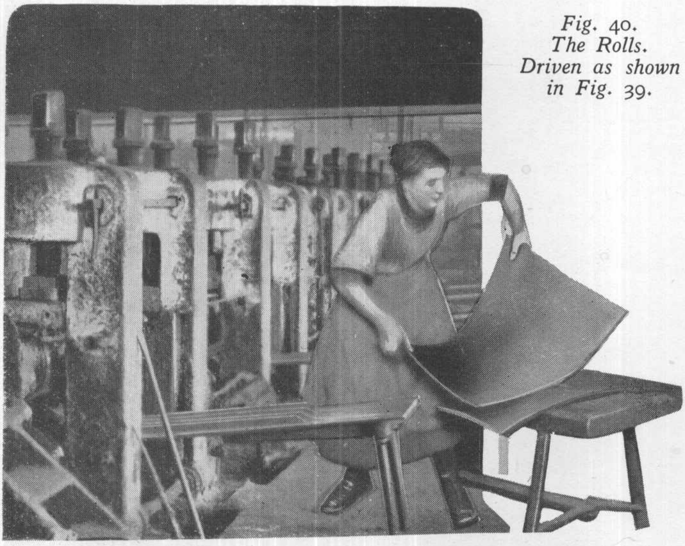


Fig. 40.
The Rolls.
Driven as shown in Fig. 39.

Fig. 45 (see page 84), in order to check the vibrations caused by a violently fluctuating load.

In colliery work rope drives are often a necessity. Reliability and hardiness are two virtues demanded and received from ropes in this department of activity. A colliery ventilating fan drive is illustrated in Fig. 46 (see page 85). The very lives of hundreds of men often depend upon this kind of drive, so that it will be appreciated that we have not spoken without reason of the unique properties of rope driving for guarding against sudden breakdown. Another fan drive is shown in Fig. 47 (see page 86) ; this time the prime mover is an electro-motor.

Fig. 48 (see page 87), illustrates a further example of colliery work; this time the drive being to haulage plant where resilience and reliability are two outstanding features of first importance. Lastly, Fig. 49 (see page 88), is included to show quite a different departure, but still in the coal mining industry. These drives to coal washing plant have a very arduous task under very inimical conditions, but the ones illustrated have performed their duty with sturdy faithfulness for a long time past

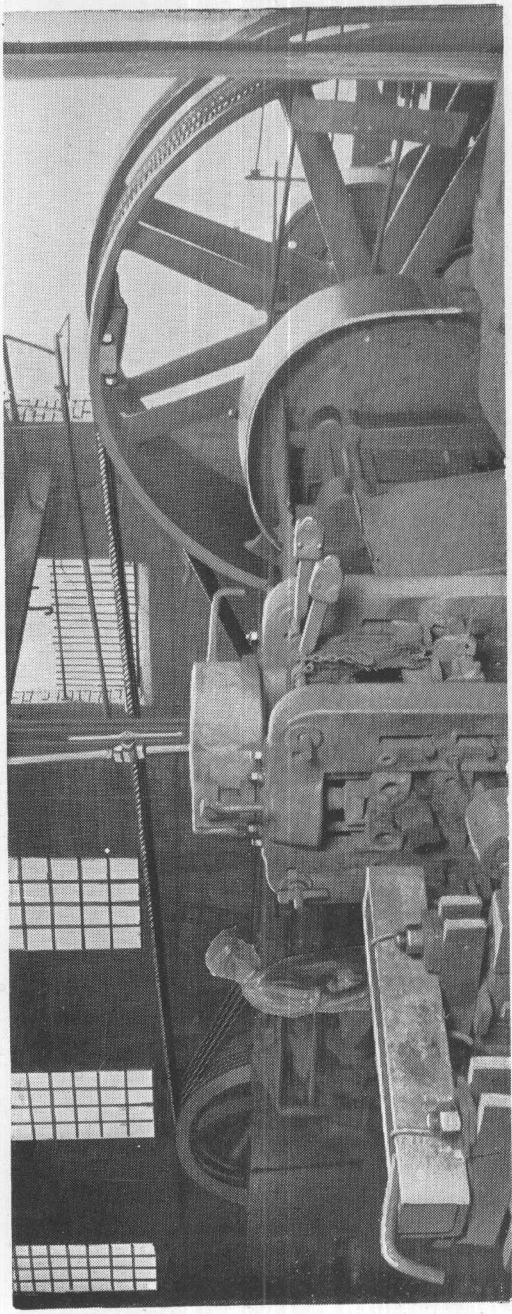


Fig. 41.

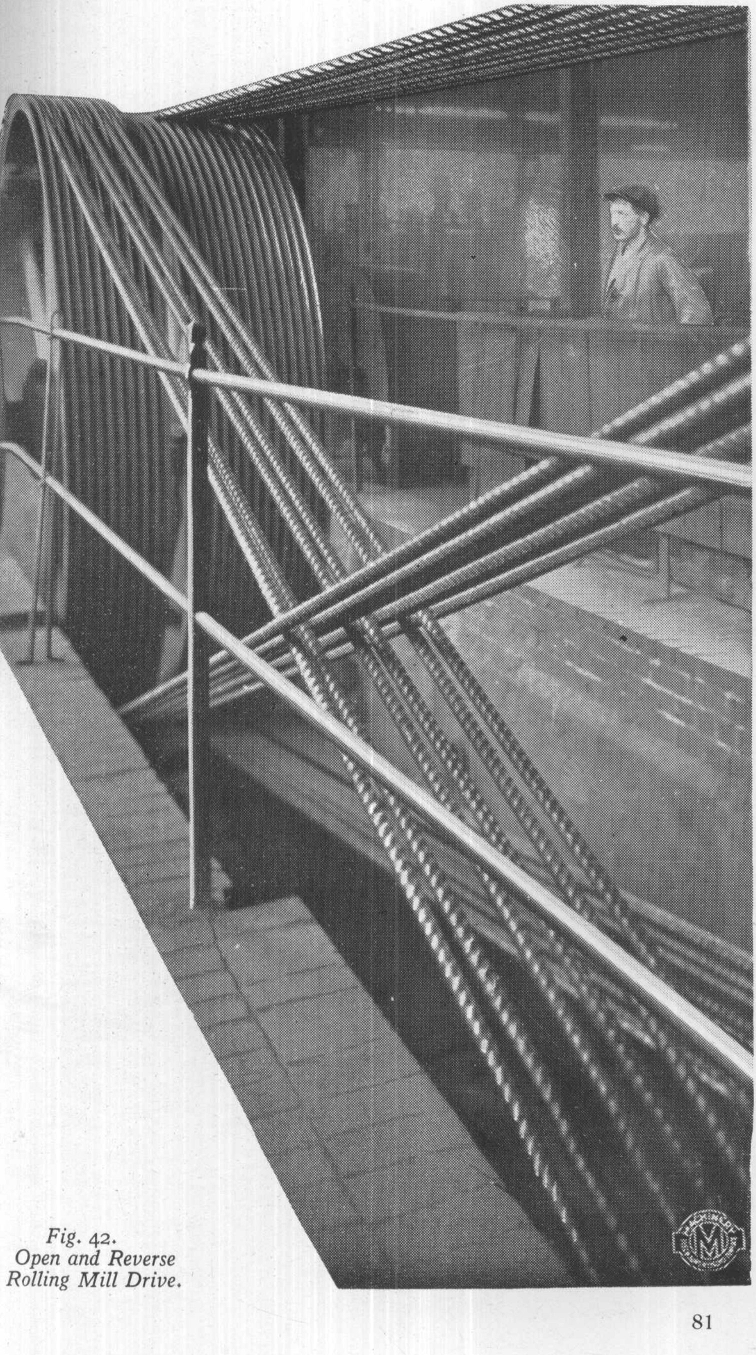


Fig. 42.
Open and Reverse
Rolling Mill Drive.

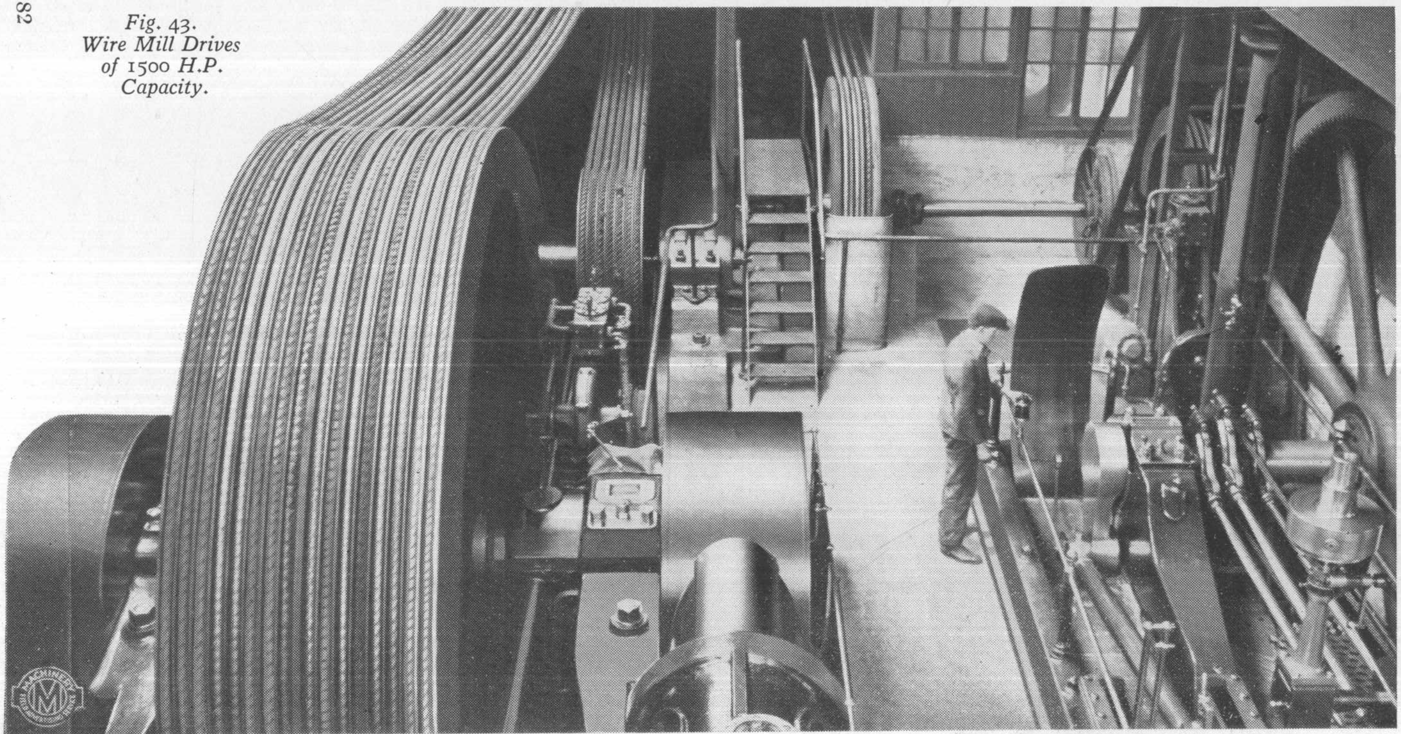


*Fig. 43.
Wire Mill Drives
of 1500 H.P.
Capacity.*

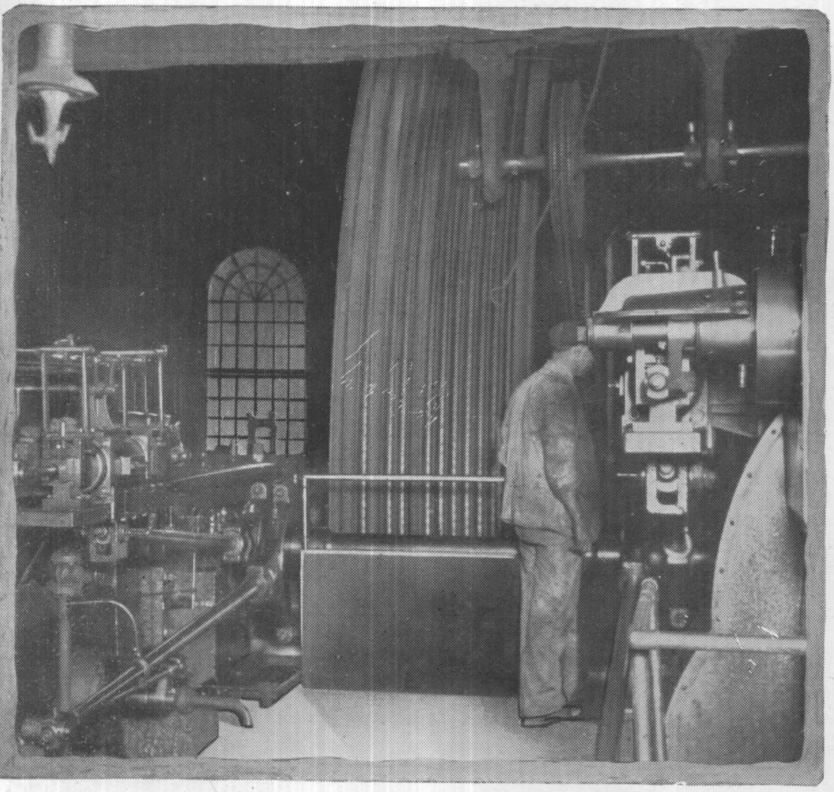


Fig. 44.
Rolling Mill Drive at 6,000 *F.P.M.*

and will continue to do so for a longer time in the future. One drive has been installed to Colliery Washing Plant with a centre distance of 55 yards, no intermediate guide pulleys of any kind being employed.

We may now turn to a very different series of applications. The iron, steel and coal industries present a grim and somewhat thankless task ; the conditions are often as bad as they can be, and credit for feats achieved is often but sparingly granted.

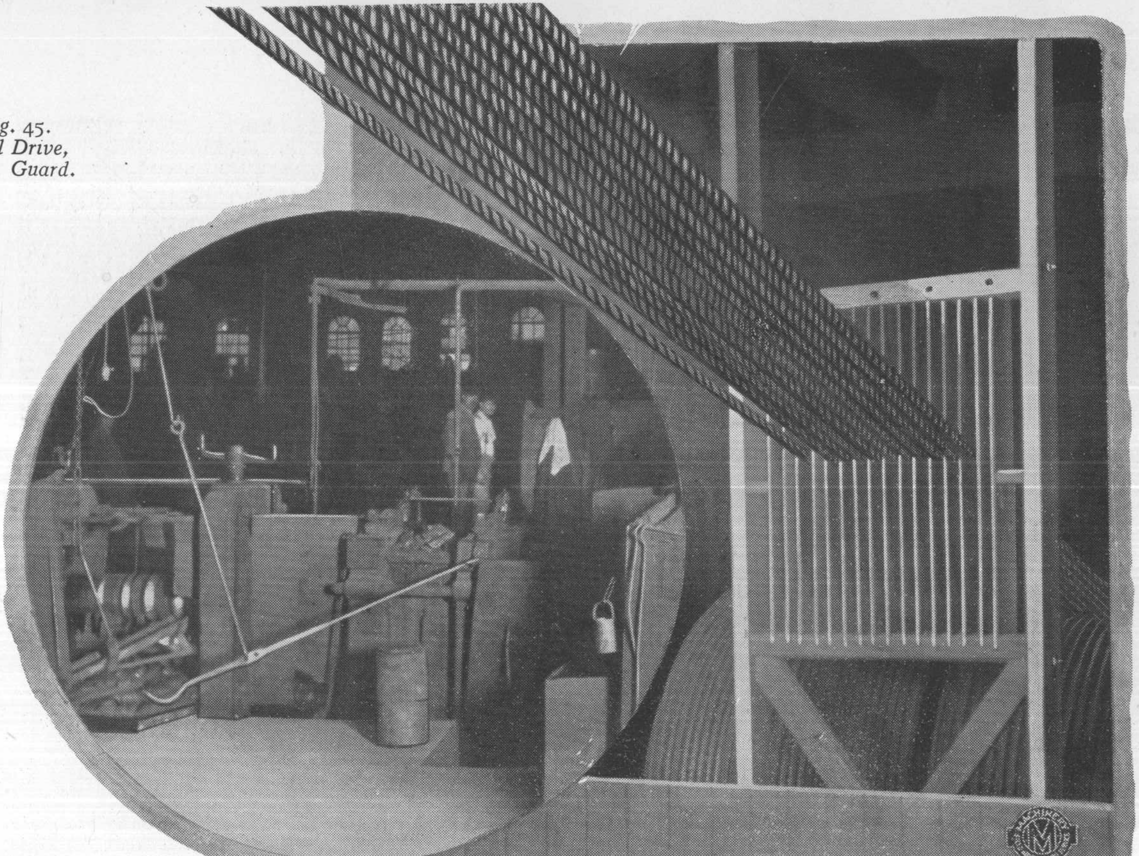


Fig. 45.
Mill Drive,
with Guard.

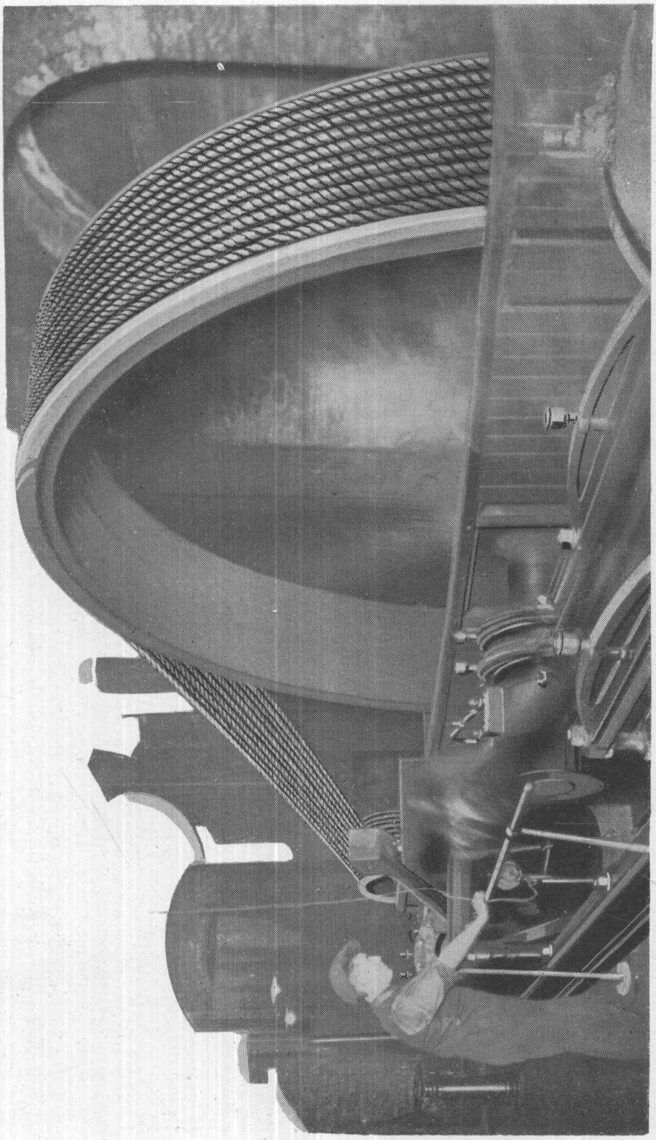


Fig. 46. Colliery Fan Drive.

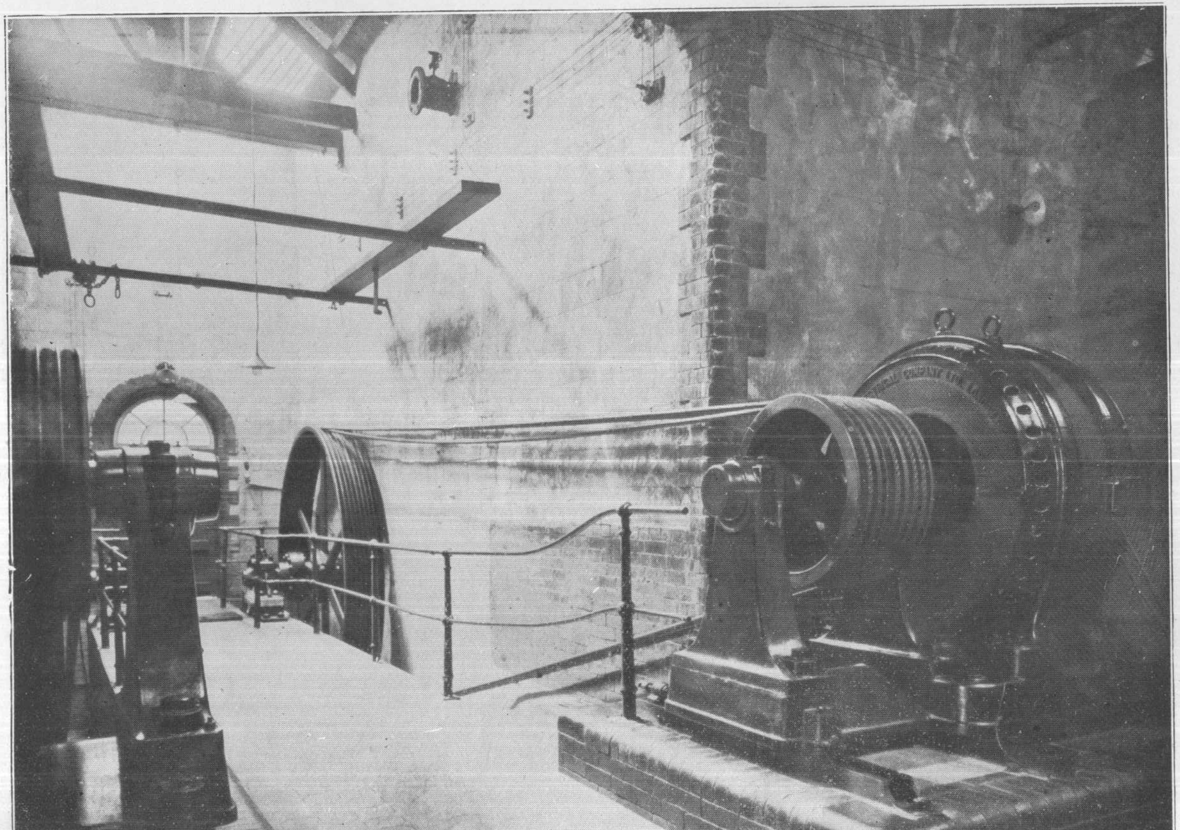


Fig. 47.
Ventilating
Fan Drive.

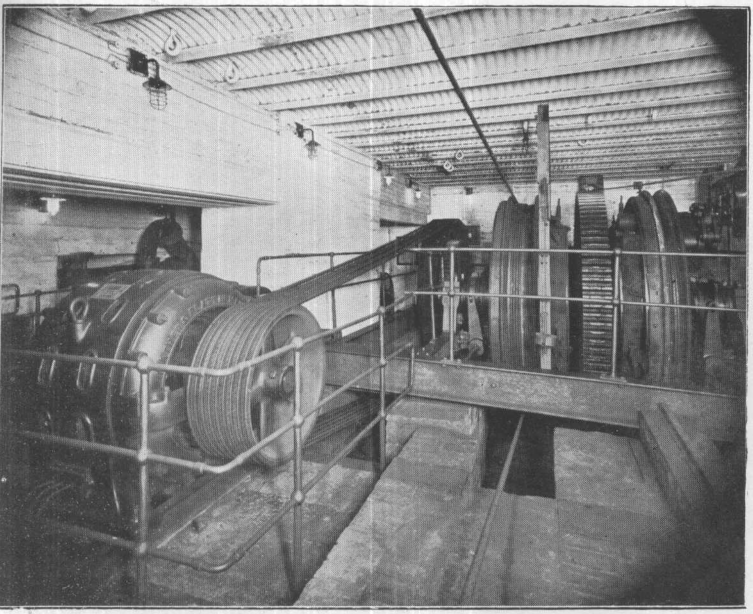


Fig. 48.
Haulage Drive at Colliery.

Different altogether are the circumstances of the drive shown in Fig. 50 (see page 89), which is the main drive of a great London Flour Mill. In such a case as this, cleanliness is one of the first essentials, and the environment of these drives is often of such a nature as to induce better results in terms of rope life than is obtained from those industries formerly mentioned. Another type of flour mill drive is shown in Fig. 51 (see page 90); this is from a motor placed conveniently near the machines which it is required to drive, such as the rollers illustrated in Fig. 52 (see page 90).

Fig. 53 (see page 91), shows a typical paper mill drive transmitting 1,400 H.P., the class of machinery driven being inset above this illustration. Another typical paper mill drive is given in Fig. 54 (see page 92).

It should be remembered that both flour mills and paper mills

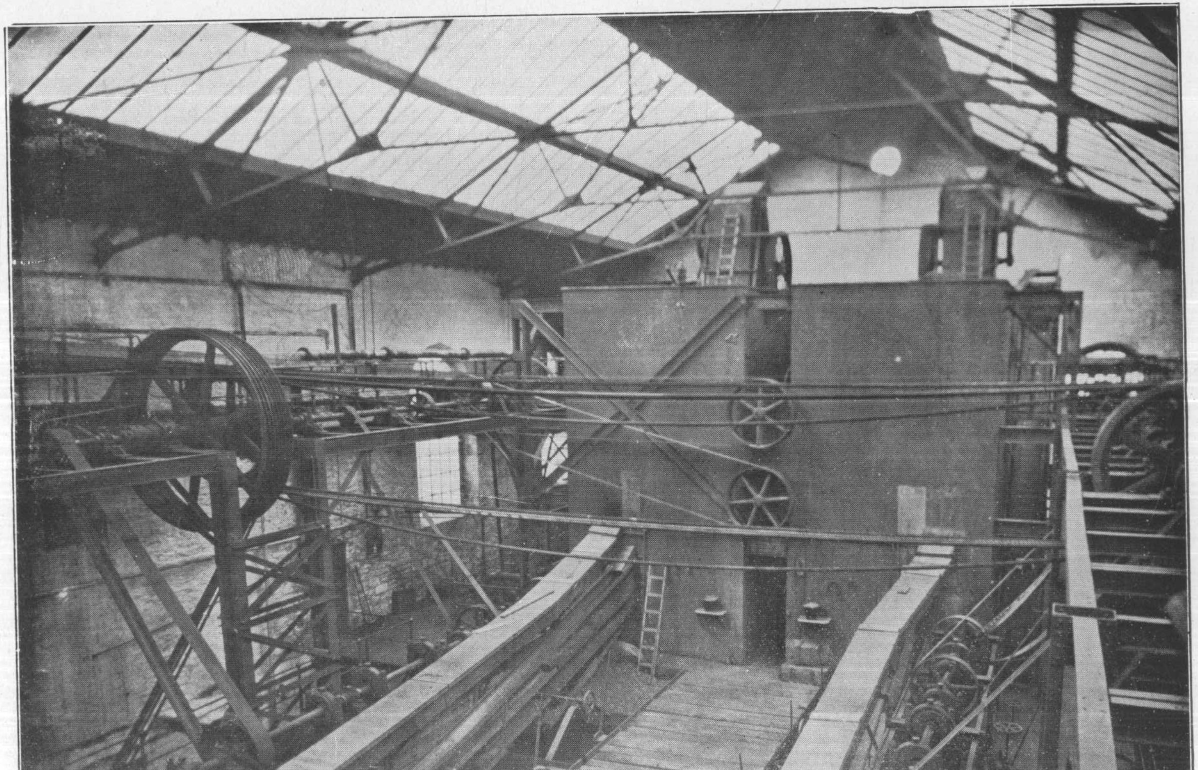


Fig. 49.
Coal Washing

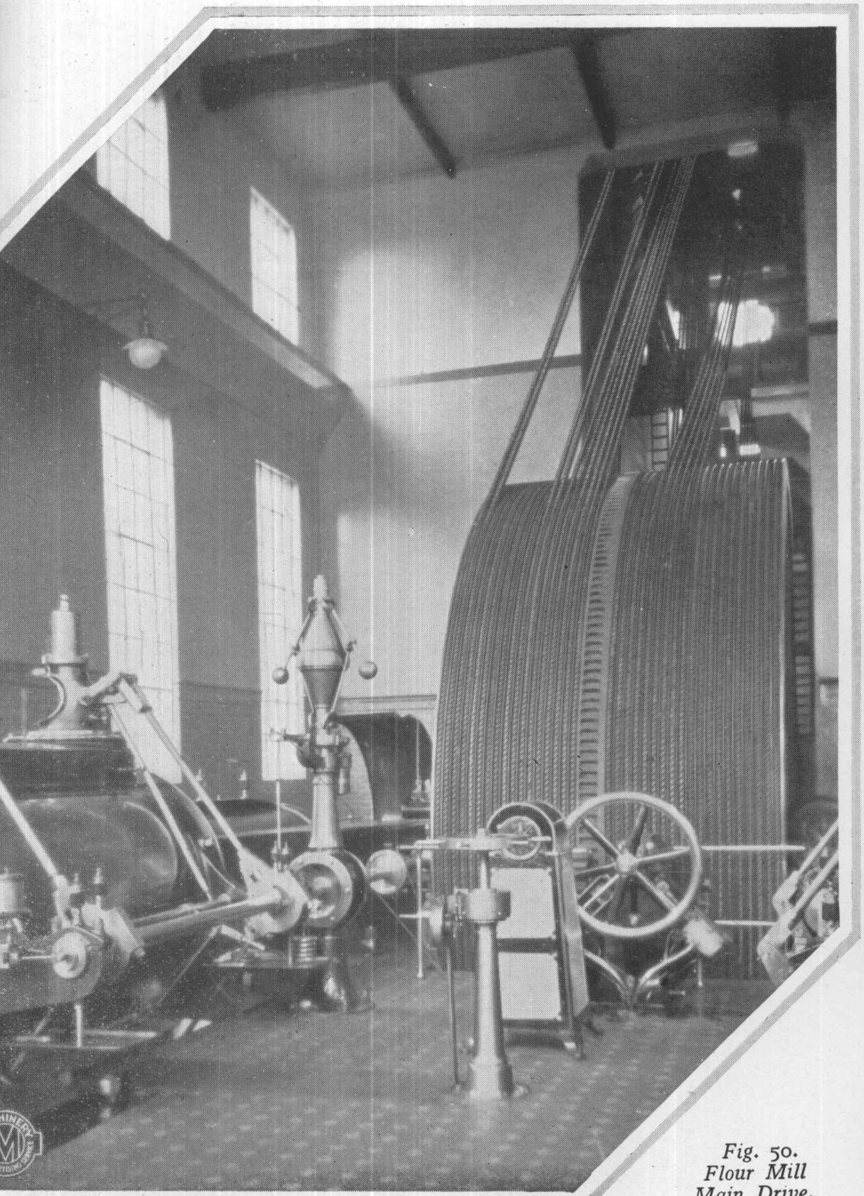


Fig. 50.
Flour Mill
Main Drive.

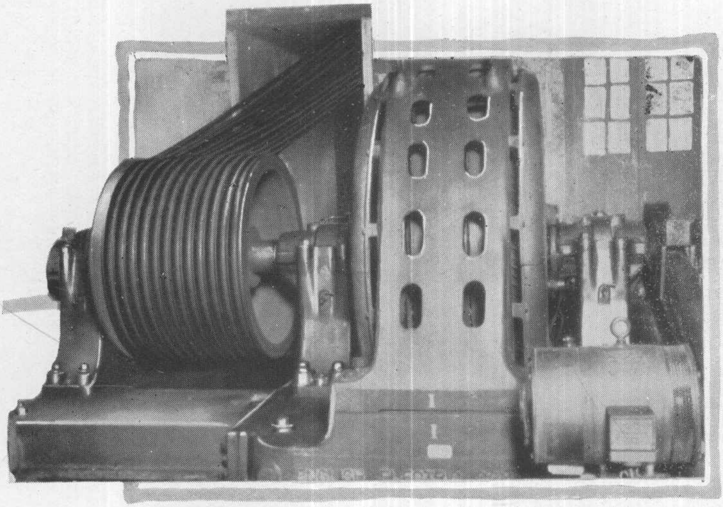


Fig. 51. *Motor Drive in Flour Mill.*

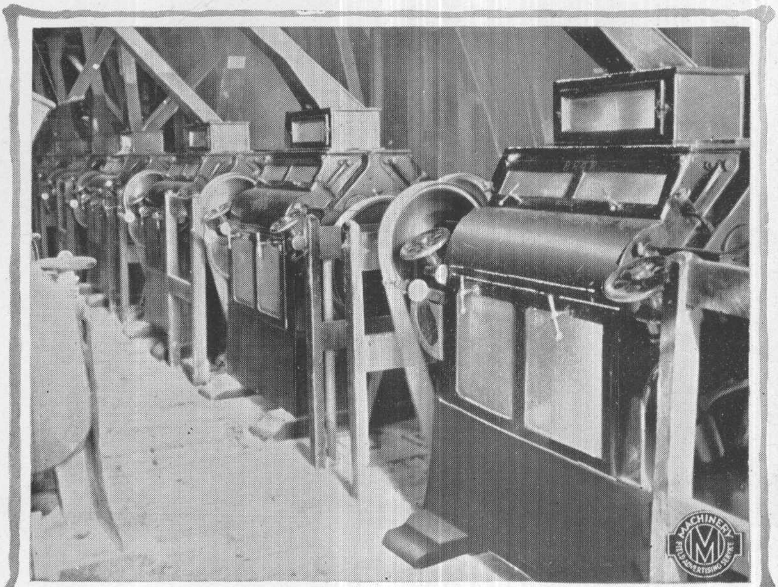
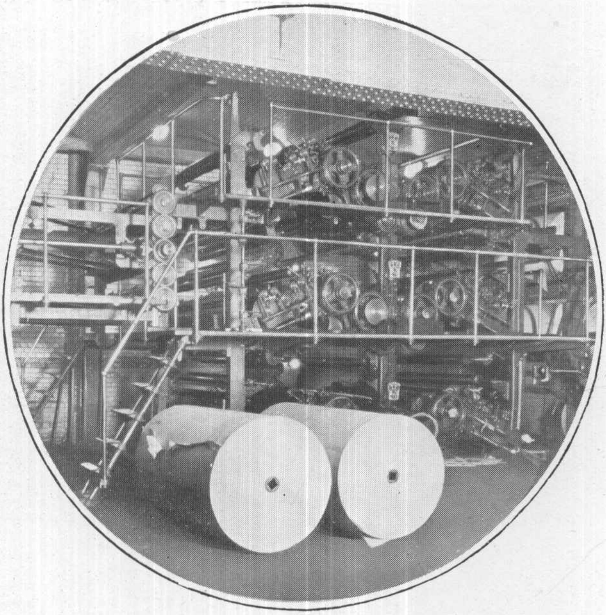


Fig. 52.



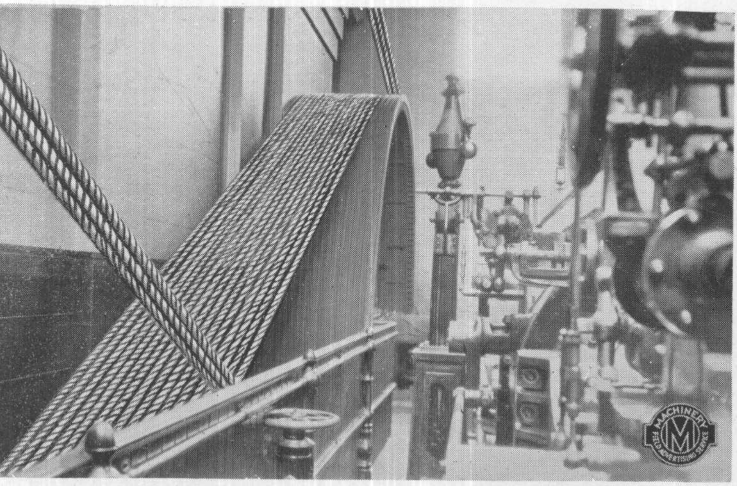


Fig. 53.
Paper Machine Drive.

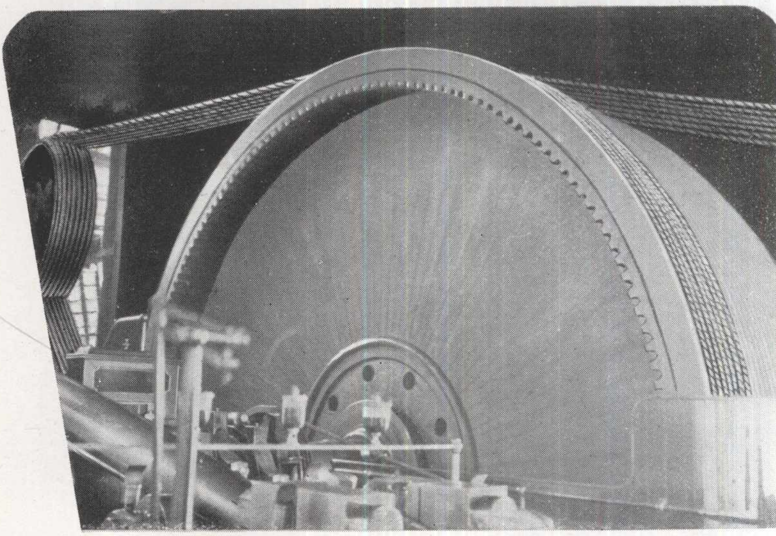


Fig. 54.
Paper Mill Drive.

run continuously from Monday morning to Saturday afternoon, and any enforced stoppage through defective transmission would not be tolerated.

From this we pass to, perhaps, the most important of all the branches of industry to which rope driving has been applied. This is the textile industry, which was the pioneer of its application, and, as such, deserves pride of place in this chapter. Numerous illustrations have already been given of textile mill drives, including the frontispiece and Figs. 6, 7 and 14. We now give Figs. 55 and 56 (opposite), which show respectively the engine room of a turbine-driven cotton mill and the ring spinning room of a similar factory. Fig. 57 (see page 94), shows the rope alley of a weaving shed, where rope drives are practically essential as a buffer between the very shocky load of the looms and the prime mover.

A turbine drive in a jute mill is shown in the next illustration, Fig. 58 (see page 95). The main drive to a woollen mill from the same kind of prime mover is illustrated in Fig. 59 (see page 95).

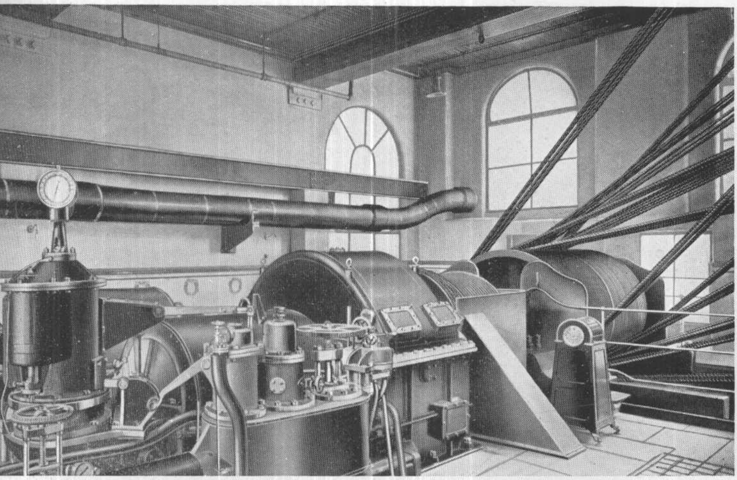


Fig. 55.
Turbine House of Cotton Mill.

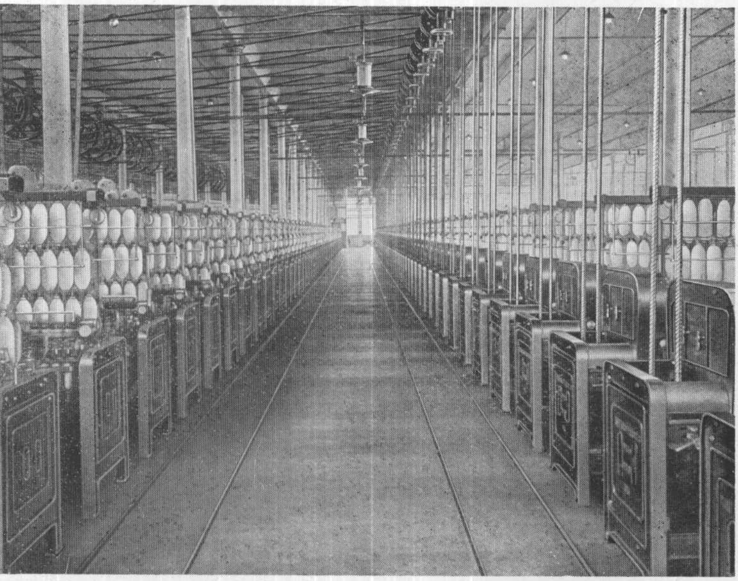


Fig. 56.
Ring Spinning Room of Cotton Mill.

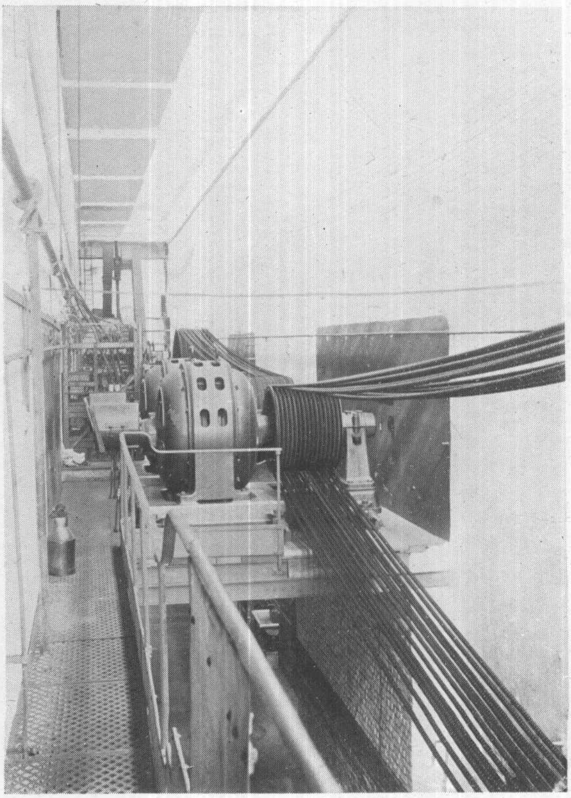


Fig. 57. Weaving Shed Drives.

The rapid growth in popularity of the uses of electricity ha opened a very wide field for rope driving. Motors an generators, however conservative their design or sturdy thei construction, are generally very susceptible to rough handling Smooth running is always to be desired, and rope driving i the only means capable of achieving this in a satisfactor manner. Again, the even torque of an electro-motor is on of its greatest advantages, but since direct-coupling is seldom advisable, the benefits accruing from this are often lost in a unsuitable transmitting medium. Rope drives, however, wil

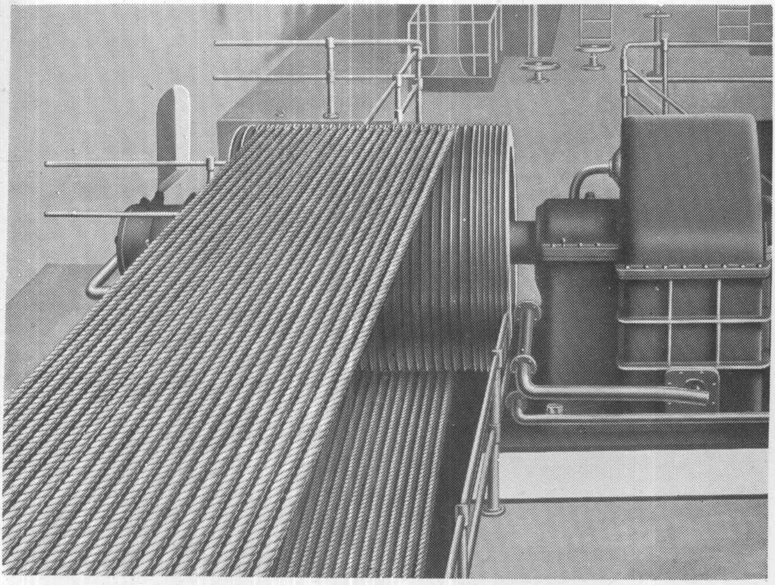


Fig. 58. *Turbine Drive in Jute Mill.*

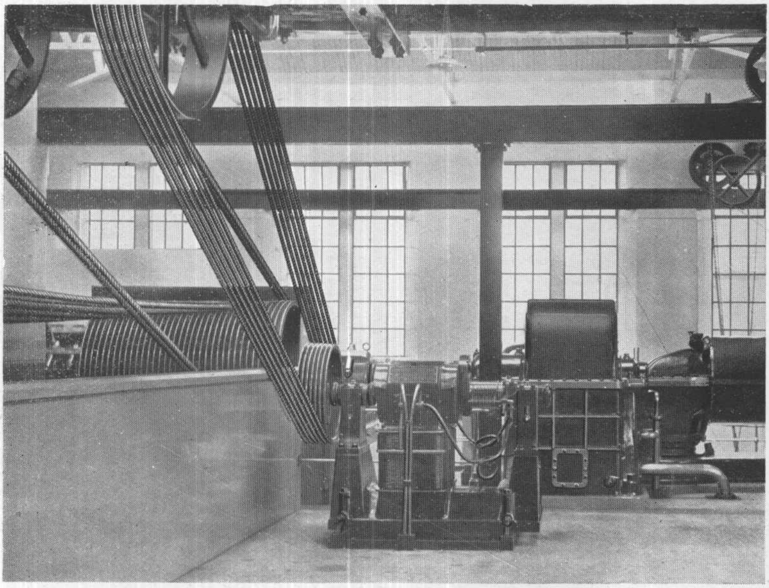


Fig. 59. *Main Turbine Drive in Woollen Mill.*

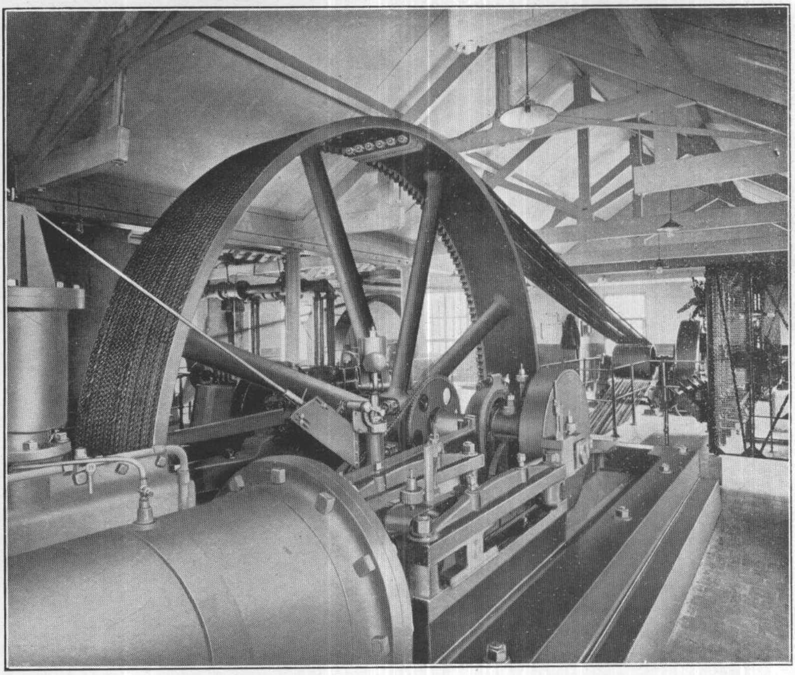


Fig. 60.
Colliery Generator Drive.

always transmit a torque without any ill effect on its steadiness ;* a property which strongly recommends the system to all electrical engineers.

A great number of illustrations of electrical drives have already been given, so that one or two more special cases will suffice. In Figs. 60 and 61 are given two views of a large drive to a generator at a Midlands Colliery. This was completely installed by us under a comprehensive guarantee. As a point of interest, attention is directed to the ropes on the flywheel in Fig. 60. This photograph being taken soon after the ropes were put on, the splices can easily be distinguished in several ropes, due to the whiter laid-in strands.

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*See the " Driving of Spinning Frames " booklet, in which this subject is fully discussed and demonstrated.

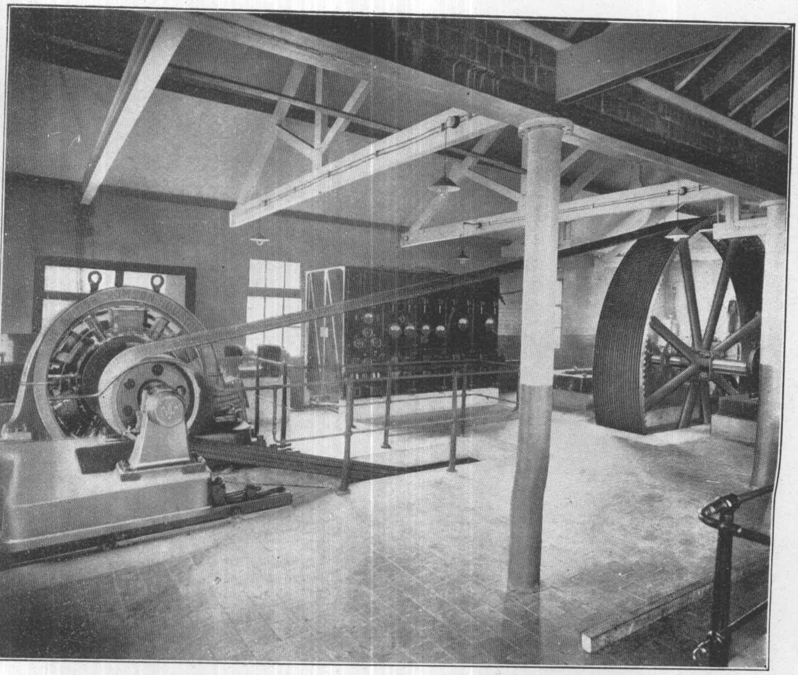

Fig. 61.

These splices, however, would be indistinguishable to the untrained eye after a few weeks' running.

Two other examples of electrical driving are shown in Figs. 62 and 63 (see pages 98-99); these are both motor drives and representative of common practice.

Coming now to the individual driving of machinery, the reader is referred to Fig. 32 (see page 59) for an example of woodworking machinery driven by means of ropes. A further example is given in Fig. 64 (see page 100), this being a circular saw driven by one $\frac{5}{8}''$ diameter rope on to a 14″ diameter fast and loose pulleys on the saw spindle which runs at 1,400 R.P.M. The rope velocity is 5,130 F.P.M. approximately, and it has run for over eighteen months without any trouble, though in constant use. Fig. 65 (see page 101), shows another high-speed, small-pulley drive, but

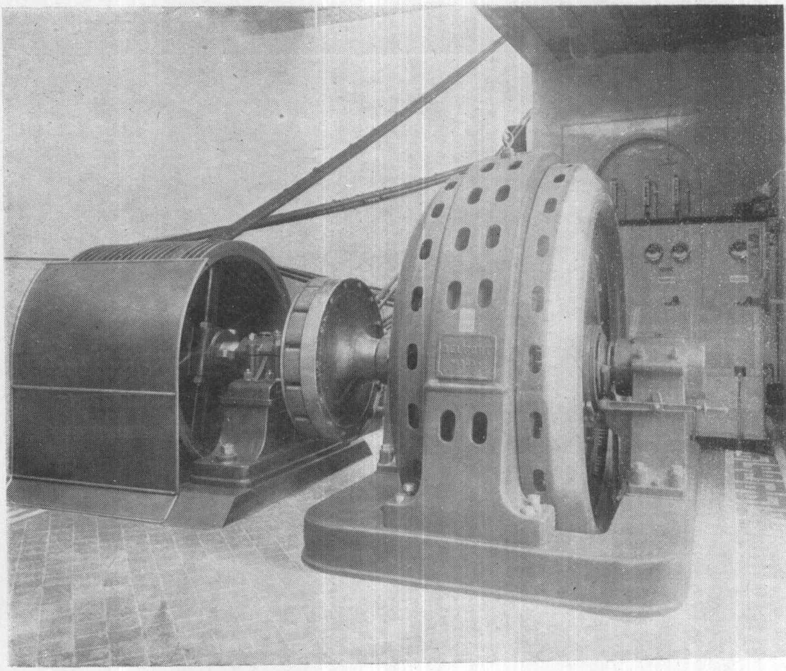

Fig. 62.

this time to a disintegrator used for breaking up fibrous material. The disintegrator drive can be seen on the right. The mean load is about 20 H.P. and the five ½″ diameter ropes on the horizontal drive have transmitted this power for over fifteen months to the present date without giving the least trouble. The machine pulley is 5·75″ diameter revolving at a mean speed of 3,800 R.P.M., the rope velocity being 5,720 F.P.M.

Another example of the very successful application of rope driving to single machine drives is found in most textile mills. This is the driving of the ring-spinning frame, a good illustration of this type of drive being shown in mass in Fig. 56, and again for one frame in Figs. 66 and 67 (see pages 102-103). The former of the last two illustrations shows the rope driving the frame through fast and loose pulleys, whilst the latter shows the drive by means of the "Weilding" friction clutch.*

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* See separate leaflet.

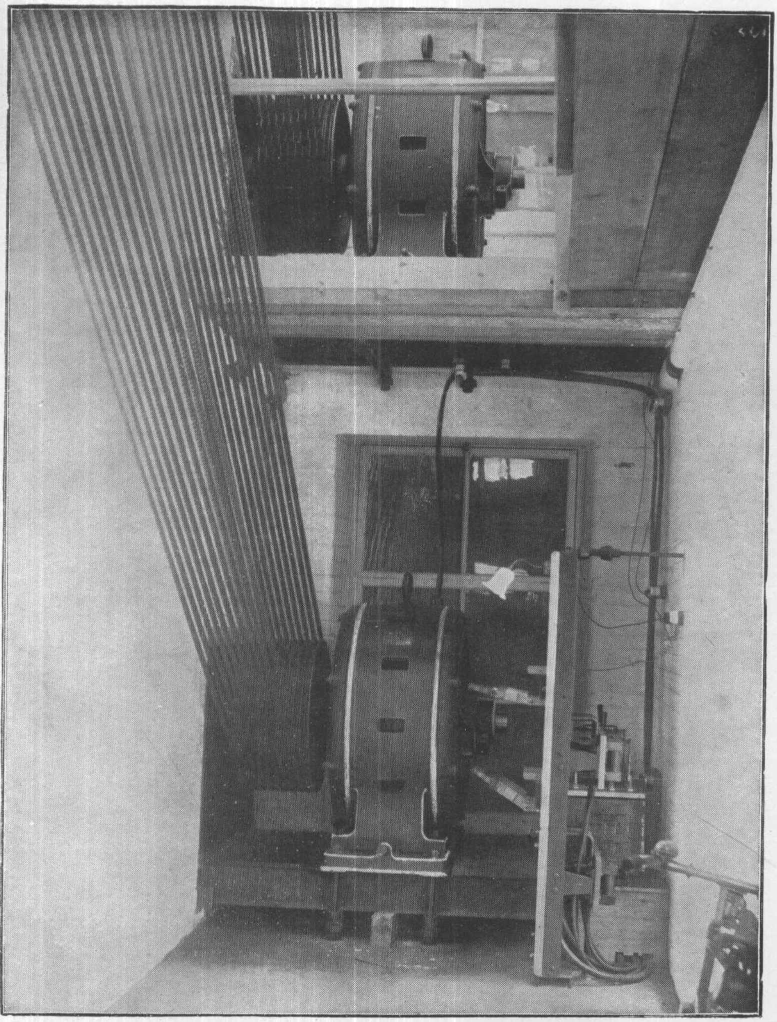

Fig. 63.

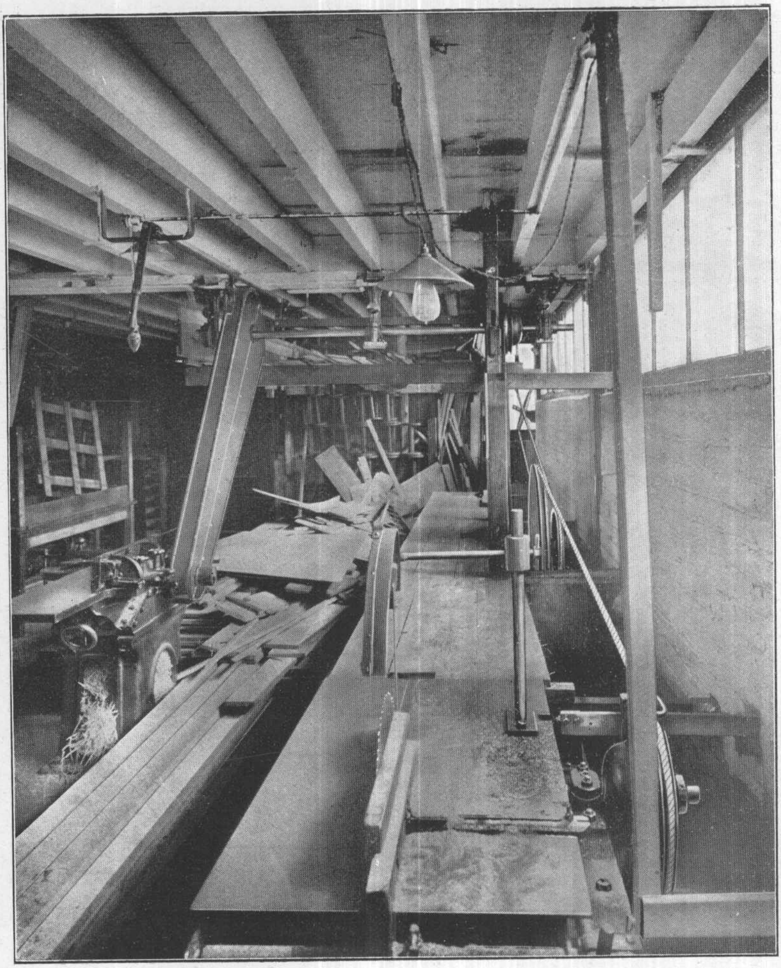

Fig. 64.
Circular Wood Saw driven at 1,400 R.P.M. by one ⅝in. rope, on fast and loose rope pulleys.

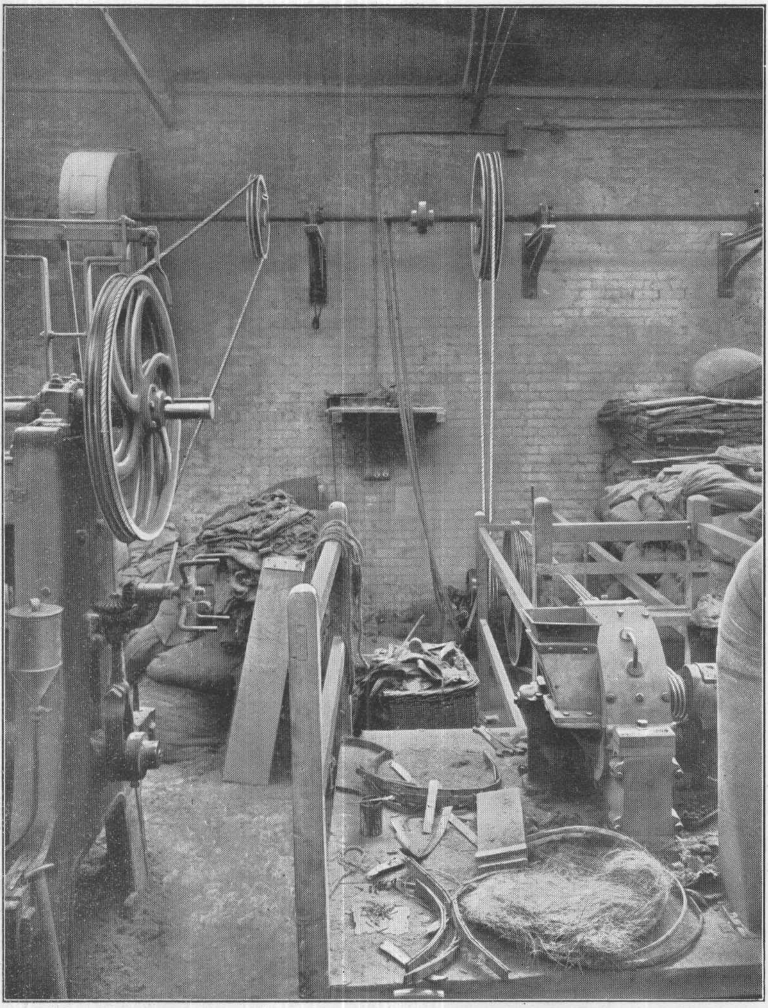

Fig. 65.
High-speed Disintegrator Drive.

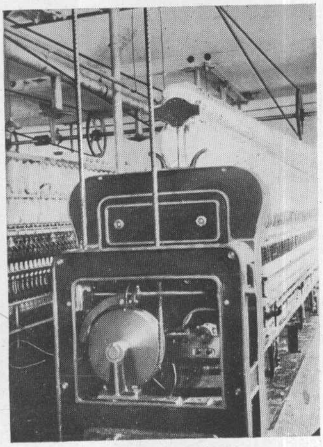

Fig. 66.
Fast and Loose Pulleys on Rope-driven Spinning Frame.

Rope driving has also been extensively applied, and with signal success, to machine-tool drives of all kinds, including drilling machines, slotting machines, lathes, emery wheels, grindstones, punches, shearing machines, presses, drop stamps, etc.

The ceramic industry is another which makes wide uses of the many advantages of rope driving. Unfortunately, the service obtained from potters' drives has not always been so good as it should have been. This is the old, old story of neglect or ignorance of first principles over again. The chief causes of trouble in the potteries are pulleys too small for the ropes, ropes overloaded out of all reason, pulleys out of alignment, and a failure to understand the essentials of angular driving.

Rope drives are very commonly used to drive the potters' wheels or "jiggers," a single rope $\frac{5}{8}''$ or $\frac{3}{4}''$ diameter and of inordinate length traverses tortuously through many "jigger" rooms. Often the same rope is used to drive a "slip-house," and several ventilating fans scattered about in different positions, each with about a 3″ or 4″ diameter driving pulley. It is consequently no wonder that the rope scarcely lasts six months. Each room should have a separate drive wherever possible; this simplifies the arrangement, tends to localise very deleterious effects, and when a rope breaks only one room is affected instead of the whole mill. Fans and all very small pulleys taking power from the rope should be driven by means of countershafts, on which the main rope drives a pulley of reasonable diameter. From this countershaft a small band can drive the fan more efficiently and economically.

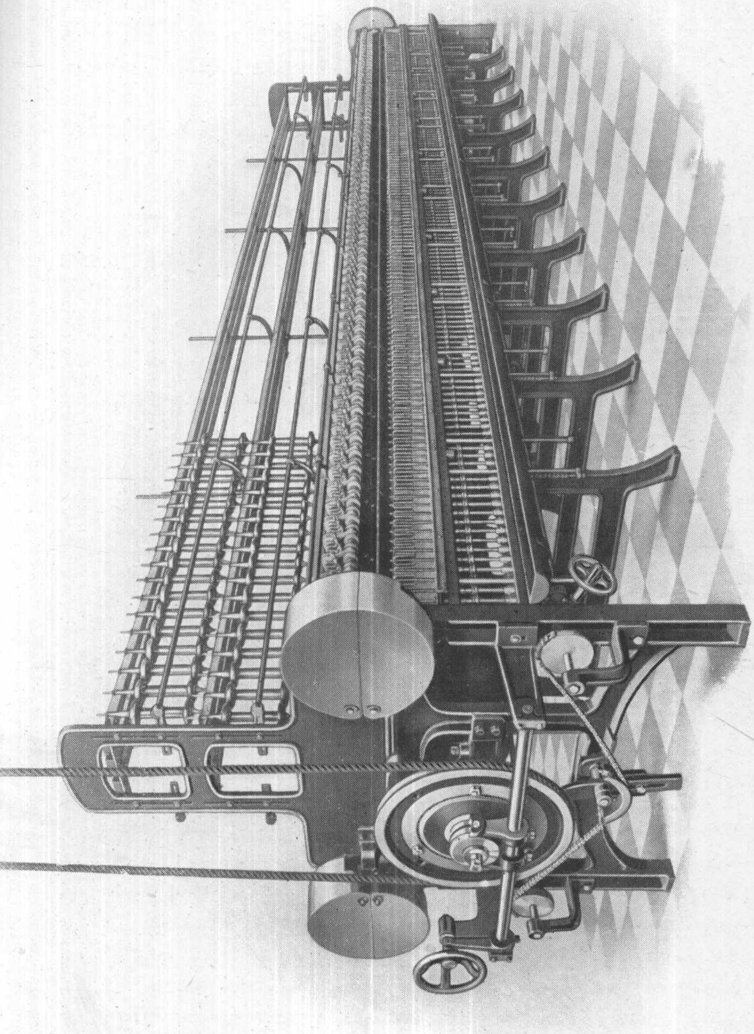

Fig. 67.
Spinning Frame driven by Rope through "Weildang" Clutch.

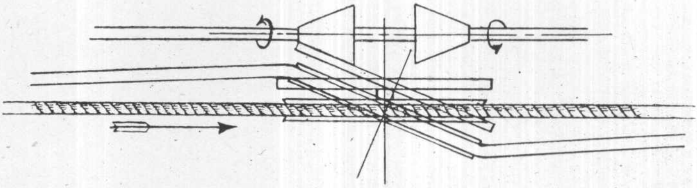

Fig. 68.
Bad type of Reverse Drive for Potter's Lathe.

These pottery drives are almost always arranged in single ropes with a tension weight at same point. This is generally essential on account of the length of the drives and the number of turns and angles in it. There should always be ample space left for the tension carriage to fall.

Potters' lathes have generally to be driven from these ropes, and, since they must be capable of instantaneous reversal, various devices are used to attain this end. Fig. 68 shows one method of obtaining the reverse, but this is one to be avoided ; the pulley is twisted out of alignment when it has to transmit power, and the distortion has an exceedingly bad effect on the rope. In Fig. 69 is shown a much better method.

Rope driving has been used extensively in the potteries purely and simply because no other method of driving can survive the terrible conditions. These can and should be improved, however, and by so doing the service obtained from the ropes would be considerably improved also.

All the examples quoted and illustrated in the previous pages constitute an infinitesimal fraction of the total number of rope drives now working with absolute satisfaction. To get these good results it is, of course, necessary to conform to certain rules. In the first place, the drive should not be called upon to perform more than its legitimate duty.

The determination of the power transmissible by a rope drive depends upon a large number of factors, all of which may vary. This subject is discussed in our booklet on " Theory of Rope

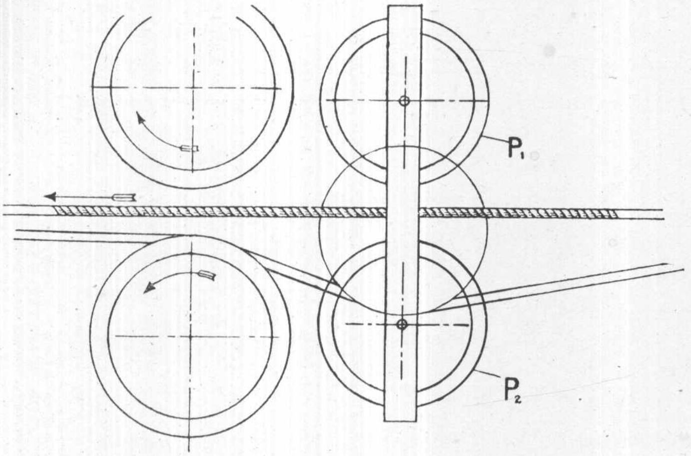

Fig. 69.
Good type of Reverse Drive for Potter's Lathe.

Driving," but for the guidance of rope users we include in Table V. (see pages 106-107) a list of horse powers which gives the figures at which it is safe to rely for normal conditions of load, inclination, centre distance, atmosphere, temperature, etc. These figures summarise the Horse-power Curves in our "Theory Booklet." Then, besides duty, there is the very important factor of ratio between pulley diameter and rope diameter. In the past, the rule that "the pulley shall be at least thirty times as large in diameter as the rope" has answered very well for general practice, but during recent years, when limits of all kinds have been extended, the rule has no longer had the same general usefulness. Factors such as velocity and rate of loading affect the permissible minimum ratio of pulley diameter to rope diameter necessary for an economic life. Variations in these therefore necessitate alterations in the ratio and the constant value of thirty would, in some instances, lead to very unsatisfactory results. This subject is treated at greater length in a separate booklet, and complete sets of curves are given showing the variations in these permissible minimum values.

We give on page 108 a table of values for minimum advisable pulley diameters taken from these curves.

Table V.

TABLE OF HORSE POWERS

FOR PATENT INTER-STRANDED COTTON DRIVING ROPES

Rope Diam. Velocity in ft. per minute.	$\frac{1}{2}$ in.	$\frac{5}{8}$ in.	$\frac{3}{4}$ in.	$\frac{7}{8}$ in.	1 in.	$1\frac{1}{8}$ in.	$1\frac{1}{4}$ in.	$1\frac{3}{8}$ in.	$1\frac{1}{2}$ in.	$1\frac{5}{8}$ in.	$1\frac{3}{4}$ in.	$1\frac{7}{8}$ in.	2 in.
1000	1·	1·6	2·3	3·2	4·2	5·3	6·6	8·	9·5	11·2	13·	14·9	17·
1100	1·2	1·8	2·6	3·6	4·7	5·9	7·4	8·9	10·6	12·5	14·5	16·7	19·
1200	1·3	2·	2·9	4·	5·2	6·5	8·1	9·8	11·7	13·8	16·	18·5	20·9
1300	1·4	2·2	3·2	4·4	5·7	7·1	8·8	10·7	12·8	15·1	17·5	20·2	22·8
1400	1·5	2·4	3·5	4·8	6·2	7·7	9·5	11·6	13·9	16·3	18·9	21·9	24·7
1500	1·6	2·6	3·8	5·2	6·7	8·3	10·2	12·5	15·	17·5	20·3	23·5	26·5
1600	1·7	2·8	4·1	5·5	7·1	8·9	10·9	13·4	16·	18·7	21·7	25·	28·3
1700	1·8	3·	4·4	5·8	7·5	9·5	11·6	14·2	17·	19·9	23·1	26·5	30·1
1800	1·9	3·2	4·6	6·1	7·9	10·1	12·3	15·	18·	21·	24·4	28·	31·8
1900	2·	3·4	4·8	6·4	8·3	10·7	13·	15·8	18·9	22·1	25·7	29·5	33·5
2000	2·1	3·6	5·	6·7	8·7	11·2	13·7	16·6	19·8	23·2	27·	31·	35·2
2100	2·2	3·8	5·2	7·	9·1	11·7	14·4	17·3	20·7	24·3	28·2	32·5	36·8
2200	2·3	3·9	5·4	7·3	9·5	12·2	15·1	18·	21·6	25·4	29·4	33·9	38·4
2300	2·4	4·	5·6	7·6	9·9	12·7	15·7	18·7	22·5	26·5	30·6	35·3	39·9
2400	2·5	4·1	5·8	7·9	10·3	13·2	16·3	19·4	23·3	27·5	31·8	36·6	41·4
2500	2·6	4·2	6·	8·2	10·7	13·7	16·9	20·1	24·1	28·5	32·9	37·9	42·9
2600	2·7	4·3	6·2	8·5	11·1	14·1	17·4	20·8	24·9	29·4	34·	39·1	44·4
2700	2·8	4·4	6·4	8·8	11·4	14·5	17·9	21·5	25·7	30·3	35·1	40·3	45·8
2800	2·9	4·5	6·6	9·1	11·7	14·9	18·4	22·2	26·5	31·1	36·1	41·4	47·1
2900	3·	4·6	6·8	9·4	12·	15·3	18·9	22·8	27·2	31·9	37·1	42·5	48·4
3000	3·1	4·7	7·	9·6	12·3	15·7	19·3	23·4	27·9	32·7	38·	43·6	49·6
3100	..	4·8	7·2	9·8	12·6	16·	19·7	23·9	28·5	33·4	38·9	44·6	50·7

3200	..	4·9	7·3	10·	12·9	16·3	20·1	24·4	29·1	34·1	39·7	45·6	51·8
3300	..	5·0	7·4	10·2	13·2	16·6	20·5	24·9	29·7	34·7	40·5	46·5	52·8
3400	..	5·1	7·5	10·4	13·4	16·9	20·9	25·3	30·3	35·3	41·2	47·4	53·8
3500	..	5·2	7·6	10·6	13·6	17·2	21·3	25·7	30·8	35·9	41·9	48·3	54·7
3600	..	..	7·7	10·8	13·8	17·5	21·7	26·1	31·3	36·5	42·6	49·1	55·6
3700	..	..	7·8	11·	14·	17·8	22·	26·5	31·8	37·1	43·2	49·9	56·4
3800	..	..	7·9	11·1	14·2	18·1	22·3	26·9	32·2	37·7	43·8	50·7	57·2
3900	..	..	8·	11·2	14·4	18·3	22·6	27·3	32·6	38·3	44·4	51·4	58·
4000	..	..	8·1	11·3	14·6	18·5	22·9	27·7	33·	38·8	45·	52·1	58·8
4100	..	..	..	11·4	14·8	18·7	23·2	28·1	33·4	39·3	45·5	52·7	59·6
4200	..	..	..	11·5	15·	18·9	23·5	28·4	33·8	39·8	46·	53·3	60·3
4300	..	..	..	11·6	15·2	19·1	23·8	28·7	34·2	40·2	46·5	53·9	61·
4400	..	..	..	11·7	15·4	19·3	24·1	29·	34·6	40·6	47·	54·4	61·7
4500	..	..	..	11·8	15·6	19·5	24·4	29·3	35·	41·	47·5	54·9	62·3
4600	..	..	..	11·9	15·8	19·7	24·7	29·6	35·4	41·4	48·	55·4	62·9
4700	..	..	..	12·	16·	19·9	24·9	29·9	35·8	41·8	48·5	55·9	63·5
4800	..	..	..	12·1	16·2	20·1	25·1	30·2	36·1	42·2	49·	56·4	64·1
4900	..	..	..	12·2	16·3	20·3	25·3	30·5	36·4	42·6	49·5	56·9	64·7
5000	..	..	..	12·3	16·4	20·5	25·5	30·8	36·7	43·	50·	57·4	65·3
5100	..	..	..	..	16·5	20·7	25·7	31·1	37·	43·4	50·4	57·9	65·9
5200	..	..	..	..	16·6	20·9	25·9	31·4	37·3	43·8	50·8	58·4	66·4
5300	..	..	..	..	16·7	21·1	26·1	31·7	37·6	44·2	51·2	58·9	66·9
5400	..	..	..	..	16·8	21·3	26·3	32·	37·9	44·6	51·6	59·4	67·4
5500	..	..	..	..	16·9	21·5	26·5	32·3	38·2	45·	52·	59·9	67·9
5600	..	..	..	..	..	21·7	26·7	32·5	38·5	45·3	52·4	60·3	68·4
5700	..	..	..	..	..	21·9	26·9	32·7	38·8	45·6	52·8	60·7	68·9
5800	..	..	..	..	..	22·1	27·1	32·9	39·1	45·9	53·2	61·1	69·4
5900	..	..	..	..	..	22·2	27·3	33·1	39·4	46·2	53·6	61·5	69·9
6000	..	..	..	..	..	22·3	27·5	33·3	39·6	46·5	54·	61·9	70·4

TABLE VI.

TABLE OF MINIMUM ADVISABLE PULLEY DIAMETERS IN INCHES.

Rope Velocity in ft. per minute	ROPE DIAMETERS, IN INCHES.										
	$\frac{3}{4}''$	$\frac{7}{8}''$	1″	$1\frac{1}{8}''$	$1\frac{1}{4}''$	$1\frac{3}{8}''$	$1\frac{1}{2}''$	$1\frac{5}{8}''$	$1\frac{3}{4}''$	$1\frac{7}{8}''$	2″
1000	10	12·5	15	18	20	23	27	30	35	39	43
1500	11·5	14	16·5	19·5	22	25	29	33	38	41	46
2000	12·5	15	18	21	24	28	31	35	41	44	49
2500	14	16·5	19·5	23	26	30	34	39	43	48	53
3000	15	18	21	25	28·5	33	37	41	46	51	57
3500	16·75	19·5	23	27	31	35	40	44	49	55	60
4000	18·75	21	25	29	33	38	43	47	53	59	65
4500	20	23	27	31	36	41	46	51	57	63	70
5000	..	25	29	33·5	38·5	44	49	55	60	67	74
5500	..	27	31	36	41	47	52	58	65	72	79
6000	..	30	33	38	44	50	56	62	69	76	84
6500	..	..	36	41	47	54	59	67	74	82	90
7000	..	..	39	43	50	57	63	71	79	88	97

CHAPTER VI.

PULLEYS

IT is more necessary to lay stress on the important influence of pulley design and manufacture in relation to rope driving than is, perhaps, popularly imagined. Countless drives have been installed with unsuitable pulleys, and the system of rope driving generally has suffered much hardship solely from this cause.

Reference has already been made to the necessity of not violating a certain ratio between pulley diameter and rope diameter, and in Table VI., page 108, a series of values have been given for the smallest pulley diameters permissible under certain conditions if satisfactory life and efficiency are to be obtained. We cannot too much emphasize the importance of the rule that these minimum values are never to be ignored. On the other hand, it should always be remembered that they *are* minima, and whilst we are confident that they will guarantee economic satisfaction, we recommend that where they can be exceeded conveniently this should be done. The larger the pulleys for a given size of rope, then the lower the rate of wear and the longer the life probable.

It often happens that the pulley diameters are limited, or again, it is often very sound practice in designing a drive to decide upon a suitable rope velocity for the known conditions, and from this to work backwards. In either case the maximum permissible rope diameter must be found from our Table No. VI., or from our chart, and a small margin is here again to be desired if at all possible, that is, provided a rope is not chosen so small in diameter as to necessitate too large a number.

A common fallacy which ought to be stamped out is that on no account should ropes smaller than one inch diameter be used for transmitting high powers. Possible whip in the small ropes is sometimes advanced as an explanation for this prejudice. It is true that as the mass of the rope becomes less its period of natural vibration becomes smaller also, but this is not a matter of great import, since it is the amplitude of waves induced by fluctuating speeds in ropes that matters. This depends principally upon the magnitude of the disturbing force, so that, provided the pulleys are truthfully and concentrically turned and accurately balanced, there need be no fear that a drive of small ropes will be at any disadvantage in comparison to one comprising larger ropes.

When rope-oscillation or jumping is found to occur to a dangerous extent, its cause may be in the load, in the motive power, or in the pulleys. The first two cases are dealt with elsewhere ;* the latter is one of the reasons why we insist upon balanced pulleys for all drives. A flywheel pulley at the driven end when the load is responsible for the trouble, or a flywheel pulley at the driving end when the motive torque possesses cyclical irregularities is generally the best cure for jumping ropes.

Pulleys for rope driving are generally made of cast iron ; wrought iron, steel and wood being used occasionally.

Diameters up to 30 feet are often seen on large reciprocating engines. Up to eight or ten feet it is customary to make the pulleys solid, unless, for convenience in getting them on to their shafts, they are split into halves. Above 12 or 14 feet in diameter they are often cast in segments, irrespective of convenience in fixing.

When the smaller pulleys are required in halves, we have found it to be the best practice to cast these solid with the usual lugs for bolting together, and then to split them along weak sections left specially for this purpose. The two halves are then fitted together with bolts and turned ; this procedure ensures that the two halves of the pulley will always fit together perfectly without any overlapping of the rims.

Steel pulleys have to be built up, and since this is expensive, they are only used in cases of necessity. This is usually only when the rope velocity exceeds the safe limit for cast iron pulleys. Centrifugal stresses limit cast iron pulleys to about 6,000 F.P.M. Built-up steel pulleys have been used quite safely at velocities exceeding 8,000 F.P.M.

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*See page 123.

Pulleys constructed entirely of wood are seldom, if ever, used nowadays, but rope wheels with cast iron bosses and arms and with rims built up of maple wood in strips glued together and dried under pressure are sometimes used in the U.S.A. It is on record that one of these pulleys was run up to a speed of 28,889 feet per minute without showing any signs of failure due to centrifugal stress. The reason why pulleys with wooden rims can be run at higher speeds is that the ratio of the tensile strength to density is greater than with cast iron. Taking a good quality of cast iron and maple wood, the relative values of tensile strength per unit weight are about one to 5·4 respectively.

Wood, however, has not the hardness of cast iron, and is unsuitable for rope pulleys because it very soon wears and the grooves lose their shape. Economically, therefore, they are not as good as cast iron pulleys because they do not last anything like the same length of time.

Pulleys are sometimes made of cast iron reinforced with steel wire in the rim, but this is impracticable or too expensive in the vast majority of cases.

Cast iron pulleys should be made from specially blended iron, the selection of which is a matter requiring extensive experience and skill. A hard metal should be used which has a close grain and leaves a smooth surface after machining, yet does not possess a too high percentage of free carbon. The castings should be quite free from blowholes or sandmarks. Great care is required in designing the pulleys in order to avoid excessive casting or shrinking stresses. The common causes of these are unequal cooling-off or unequal distribution of metal in the arms, rim and boss. Should the rim cool off first and set whilst the arms are still hot, and perhaps even plastic in the centre, then, in contracting, these will set up bending strains in the rim and tension in themselves. This might even cause porosity at the regions where the arms run into the rim. Often the shrinking stresses in a pulley are so great that fractures occur during the cooling of one which has been badly designed. The arms of cast iron pulleys used to be made curved, partly in order to avoid excessive shrinking stresses, and in modern practice the boss sometimes is cast in a number of segments with spaces between the arms. These are afterwards run-in with a soft metal, and steel hoops are shrunk round the outside of the boss to give the required strength, or steel stakes may be driven into the apertures and the same hooping process followed, all with the same object in view.

Many methods are employed for grooving the rims. Some makers at one time merely ground out the cored grooves with emery ; others cast pulleys in a special chill, machined to the exact size of the finished rim, the grooves being afterwards touched up with fine emery and oil. Special machines have been made to mill out the grooves, a number at a time, but these are very uncommon.

No method which does not include cutting the final shape of the grooves with a tool has ever proved satisfactory. *Furthermore, after the usual finishing cut with spring tool or other agency, the surfaces of the grooves should be given a glass polish by abrasion.* This is of extreme importance, and cannot be over-emphasized.

In Willis's " Principles of Mechanism " occurs a description of wheels for rope driving in which the grooves were furnished with spikes at the bottom, or sometimes cut into the form of teeth on the sides in order to prevent slipping. Fortunately for rope driving, this barbarous custom became extinct a long time ago, but it is to be regretted that a kind of refined revival has occurred. Even modern millwrights sometimes cherish the illusion that rope pulleys should have more or less rough groove surfaces. The " teeth " of Willis have their counterpart in the tool " chatter marks " of pulleys turned out to-day by engineers who ought to know better. It is true that this is sometimes done under the erroneous impression that the rope drive will benefit by an improved grip between pulley and rope.

This is absolutely incorrect. The co-efficient of friction between a lubricated cotton rope and a polished cast iron groove is greater than with a rough or irregularly finished one with the same angle.

Instances have occurred repeatedly in our experience, even in recent times, where ropes which should have lasted fifteen or twenty years have been completely worn out in as many months, due to nothing other than rough pulley grooves. Ultimately, of course, the rope wears these grooves by gradual degrees to a state of high polish, but during this process a quantity of rope has been worn away much greater in value than would have been the cost of polishing the pulley grooves in the lathe at the outset.

It should also be remembered that rough surfaces detract from the efficiency of the drive by the setting up of "wedging action" in the grooves. The small irregularities of the unpolished surfaces grip the softer cotton rope and tend to retain this at the point of delivery of the pulley, with the result that energy is continually wasted in dragging the rope out of its groove. With a polished surface, this is non-existent. The grip in this case depends purely upon the normal pressure between the rope and the groove face. At the section where the rope should be delivered from the pulley this normal pressure becomes zero, and the only effort required to be exerted is that of unbending the rope ; this is the only source of lost power from the ropes of a good rope drive, other than the slight amount of air friction.

After polish of the grooves and balance, there comes form, or shape of groove, in order of importance among those factors which have the most immediate bearing on the efficacy of rope drives. Three types of single grooves are shown in Figs. 70, 71 and 72 (see page 114). The first, Fig. 70, is the curved-sided groove, now, happily, but rarely encountered. It was originally supposed to counteract "differential driving," which will be discussed in a later chapter. It does not serve the purpose for which it was intended, but it tends to make ropes

" revolve," which is a detriment, and it is also a rather expensive groove to machine. Furthermore, as the rope wears and becomes slightly smaller in diameter, the angle between the faces of the groove holding it increases, with the result that slip is more liable to occur. Curved-sided grooves should therefore be avoided.

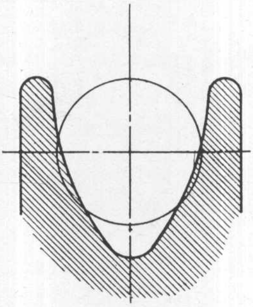


Fig. 70.
Curved sided Groove.

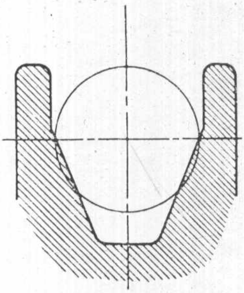


Fig. 71.
Flat-bottomed Groove.

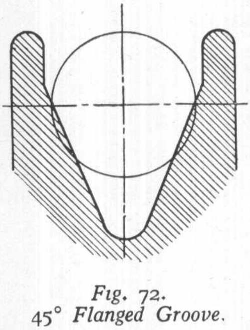


Fig. 72.
45° *Flanged Groove.*

The next type, shown in Fig. 71, is the Continental " flat-bottomed " groove, which is objectionable because a rope soon rests on the bottom. Only a very small range of sizes is permissible with this groove.

English practice at one time centred round the forty-five degree flat-sided flanged groove, as shown in Fig. 72, but has now progressed to the more suitable types to be described later.

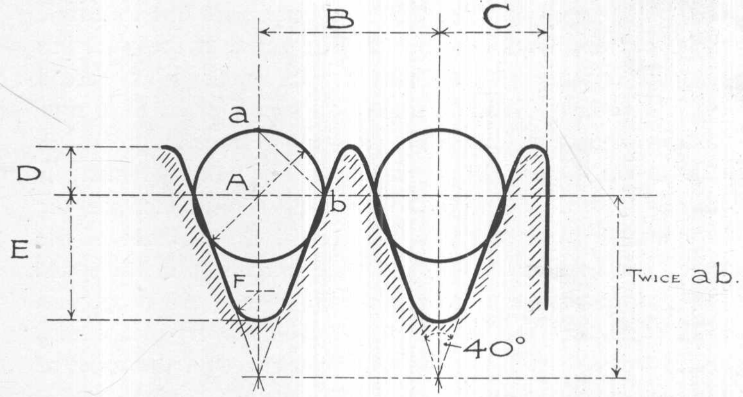
The flanges on the groove shown in Fig. 72 are intended to prevent or check rope oscillation. Experience shows that they do not do this. If a rope is given sufficient side swing to cause it to travel from one groove to another, the flanges are quite incapable of preventing this. Furthermore, there should not be so large a side impulse imparted to the ropes, and the proper remedy is to find the cause and remove that. The great majority of jumping ropes are caused by wave impulses due to erratic loads, and the amplitude in a vertical plane of the waves so produced is generally much greater than any flange ever could hope to control. Also, a slight side-swing given to a rope vibrating in this manner easily causes it to leave its groove, in spite of the largest flange possible. The proper remedy is described in Chapter VII. The flanges only increase the wear on the ropes, increase the cost of manufacture of the pulleys, and render them more liable to damage in transport. The sudden change in contour at the root of the flange is a weak point, and this is sometimes overcome by means of a liberal radius, which has the same bad effect on the ropes as a curved-sided groove.

There is no doubt but that different combinations of circumstances call for slight differences in groove angle for complete academic correctitude, but since this is not economically possible, a standard has to be adopted for the general case. Very special circumstances may occasionally justify a departure from this. It has been found that a 40° groove satisfies the majority of conditions better than the 45°. The advantage is that slightly more power may be transmitted if necessary with the former angle, whilst the back tension does not need to be so great under ordinary conditions.

The keener groove does not exert any ill effect on the ropes, but, on the contrary, has a greater tendency to cause them to fix.

It is, furthermore, a cheaper groove to machine and easier to polish properly, and, when finished, it is stronger and resists accidental chipping better. As a final advantage, we would mention that a larger range of rope diameters may be used with it. In Fig. 73 is shown a section of Kenyon's Standard 40° Flangeless Groove, together with a table of dimensions for different sizes of rope.

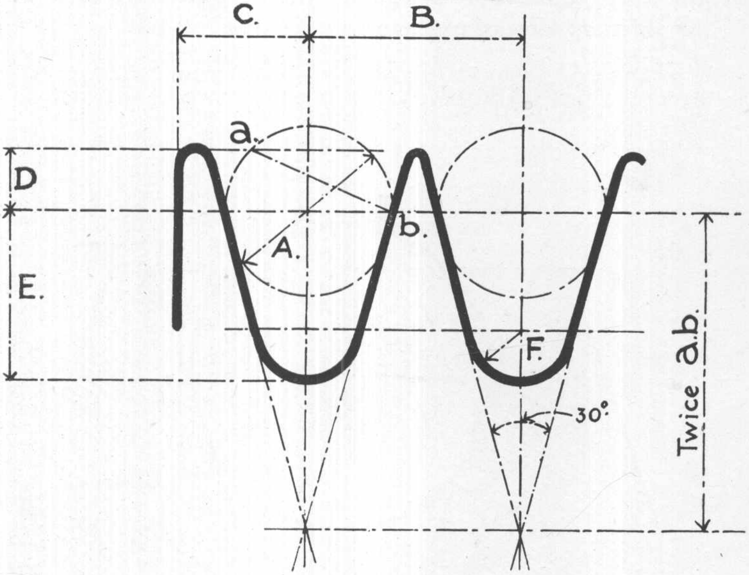
Small ropes require a somewhat keener groove because they are generally used on very small pulleys and on drives with short centre distances. In consequence of this and the results of experiments, a 30° groove has been adopted as the standard for ropes of 1″ diameter and below, except where the conditions are such as to render the wider angle permissible.



DIA. ROPE A	IN. $\frac{1}{2}$	IN. $\frac{5}{8}$	IN. $\frac{3}{4}$	IN. $\frac{13}{16}$	IN. $\frac{7}{8}$	IN. 1	IN. $1\frac{1}{8}$	IN. $1\frac{1}{4}$	IN. $1\frac{3}{8}$	IN. $1\frac{1}{2}$	IN. $1\frac{5}{8}$	IN. $1\frac{3}{4}$	IN. $1\frac{7}{8}$	IN. 2
PITCH B	$\frac{3}{4}$	$\frac{7}{8}$	$1\frac{1}{16}$	$1\frac{3}{16}$	$1\frac{3}{16}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{11}{16}$	$1\frac{7}{8}$	$2\frac{1}{16}$	$2\frac{3}{16}$	$2\frac{3}{8}$	$2\frac{9}{16}$	$2\frac{3}{4}$
C	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{25}{32}$	$\frac{13}{16}$	$\frac{15}{16}$	$1\frac{1}{16}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{5}{16}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$
D	$\frac{1}{4}$	$\frac{9}{32}$	$\frac{9}{32}$	$\frac{5}{16}$	$\frac{11}{32}$	$\frac{3}{8}$	$\frac{13}{32}$	$\frac{15}{32}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{19}{32}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{23}{32}$
E	$\frac{1}{2}$	$\frac{19}{32}$	$\frac{23}{32}$	$\frac{25}{32}$	$\frac{7}{8}$	$\frac{15}{16}$	$1\frac{1}{16}$	$1\frac{3}{16}$	$1\frac{5}{16}$	$1\frac{13}{32}$	$1\frac{9}{16}$	$1\frac{21}{32}$	$1\frac{3}{4}$	$1\frac{27}{32}$
F	$\frac{1}{8}$	$\frac{5}{32}$	$\frac{5}{32}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{7}{32}$	$\frac{1}{4}$	$\frac{9}{32}$	$\frac{5}{16}$	$\frac{11}{32}$	$\frac{3}{8}$	$\frac{13}{32}$	$\frac{7}{16}$	$\frac{15}{32}$

Fig. 73.
Kenyon's Standard Flangeless 40° *Groove.*
Table VII.

Our standard 30° groove is shown in Fig. 74, together with a table of dimensions for different sizes of rope. In case the



Dia. Rope A.	3/8"	1/2"	5/8"	3/4"	13/16"	7/8"	1"
Pitch B.	1/2"	11/16"	13/16"	1"	1 1/16"	1 1/8"	1 5/16"
C.	5/16"	7/16"	1/2"	5/8"	21/32"	11/16"	23/32"
D.	1/8"	3/16"	7/32"	1/4"	9/32"	5/16"	3/8"
E.	3/8"	17/32"	5/8"	3/4"	27/32"	55/64"	31/32"
F.	7/64"	5/32"	3/16"	7/32"	1/4"	1/4"	5/16"

Fig. 74.
Kenyon's Standard Flangeless 30° Groove.
Table VIII.

dimensions given for these two grooves are not available, we give simple geometric constructions for accurately setting them out ; Fig. 75 shows the construction for a 40° groove.

First draw a circle to represent the rope circumference. Construct the chord AB between the intersections with the circle of the horizontal and vertical centre-lines. Mark off a point on the vertical centre-line at a distance equal to twice AB below the centre of the rope circle. This is the point of intersection of the sides of the groove continued.

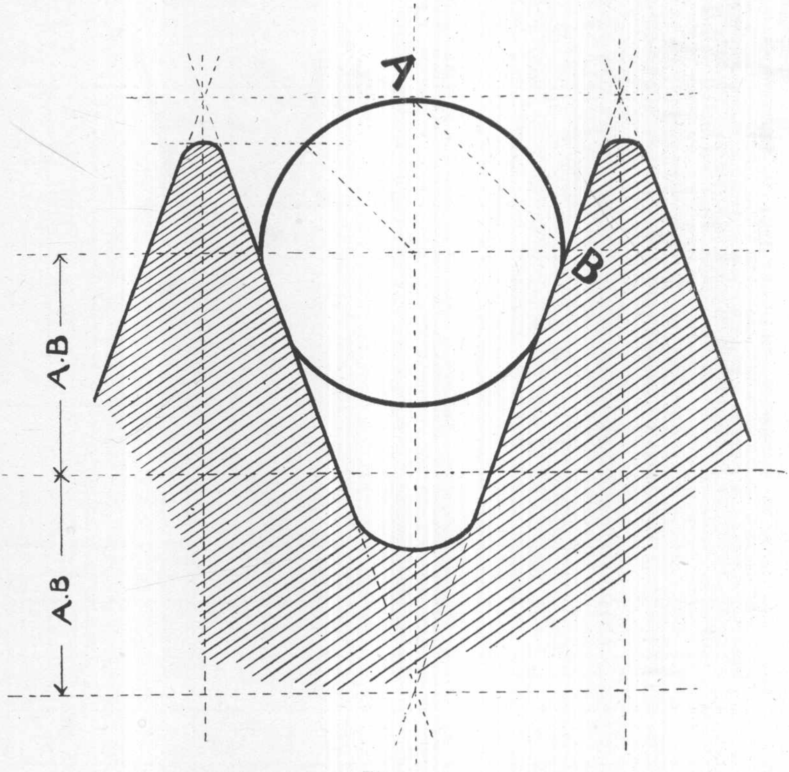


Fig. 75.
Setting out Kenyon's Standard 40° *Groove.*

The half distance marks the centre of radius for the bottom of the groove. Note that according to this construction, the sides of the groove intersect the rope circle; this amount faithfully represents the degree of rope compression which actually occurs when a rope is inserted in a groove under normal working tension. It is a mistake to assume that a rope remains as incompressible as a bar of iron between the groove faces.

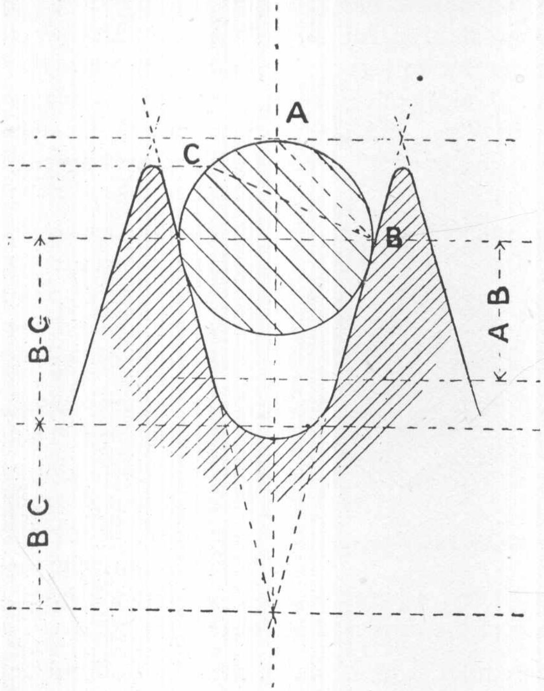


Fig. 76.
Setting out Kenyon's Standard 30° Groove.

The construction for a 30° groove is shown in Fig. 76, and is very similar to that for a 40° groove except that a measuring distance of BC is used in place of AB for the apex of the groove sides.

Guide pulleys, jockey pulleys and tension pulleys all require the same attention and skill in design and manufacture as driving pulleys. It is true that they transmit no power, but they exert every bit as much influence on the life and efficiency of the drive as those which do. They should be balanced as accurately as driving pulleys, and their grooves should be polished to the same degree of fineness. In addition, guide pulleys should always be provided with an efficient method of lubrication which can be made to function whilst the pulley is running. Grease cups are often used, and care should be taken to see that these cups are not fixed so that they revolve with the pulley, otherwise it is impossible to screw them up except when the drive is stopped. Guide pulleys should always be provided with " U " grooves of a size and shape which compels the rope to rest freely on the bottom. The usual and best shape is shown in Fig. 77.

Ball or roller bearings are often advantageous for guide pulleys because the less power they absorb the greater will be the overall efficiency of the drive.

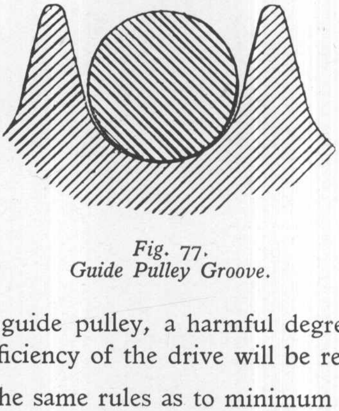


Fig. 77.
Guide Pulley Groove.

For the same reason, inclined guide pulleys should always be provided with ball thrust bearings to receive their weight. If any appreciable drag is put on to the rope by a guide pulley, a harmful degree of wear will occur, and the efficiency of the drive will be reduced.

The same rules as to minimum advisable pulley diameters for given conditions of rope diameter, speed, etc., which apply to driving pulleys, hold with equal force for guide, tension and jockey pulleys, and are violated with no less evil results.

We have patented a special improved type of guide or " gallows " pulley bracket, which is used extensively in textile mills for the driving of ring spinning frames, doubling frames, etc. This is illustrated in Fig. 78, a full description being given in a separate leaflet.* The underlying principles of this bracket are applied with equal advantage to all our adjustable guide pulleys.

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*See leaflet on the " Ruscoe Patent Adjustable Gallows Pulley Bracket."

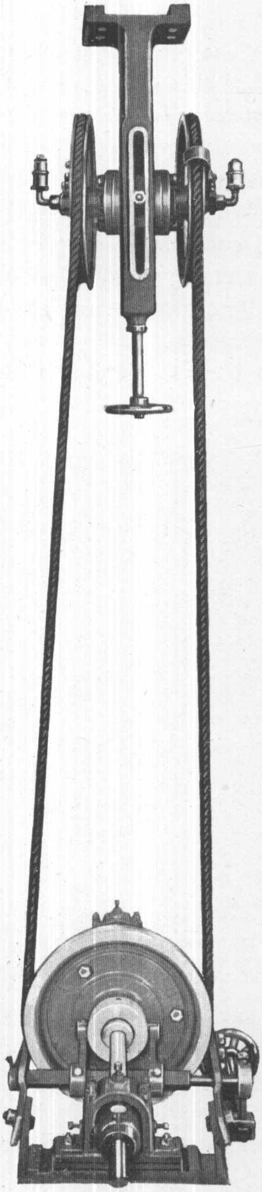

Fig. 78. The " Ruscoe " Patent Adjustable Gallows Pulley Bracket.

All pulleys are subject to the same frictional resistance from the air, the magnitude of this depending upon the speed of the pulley and its design. Very considerable savings can be effected by reducing this " windage " or air friction. With small pulleys this is usually accomplished by making them of the " plate " or " disc " type, whilst with larger pulleys this is impossible, and an equivalent effect is obtained by encasing the arms in sheet metal guards, as shown in Fig.79. This particular case is interesting because the rope velocity is over 7,000 F.P.M., and a saving of five per cent. in power is estimated to result from the use of " Windage Screens," as they are termed.*

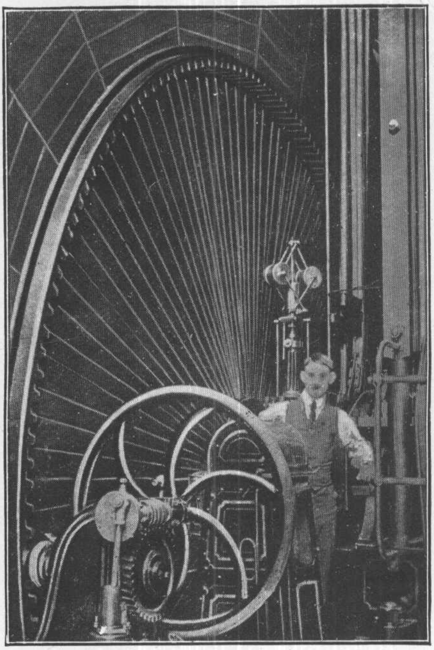

Fig. 79.
Windage Screens on large Flywheel Pulley.

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*See announcement, page 144.

CHAPTER VII.

MAINTENANCE

THE various branches of maintenance duties required with rope drives can be classified under the following headings :—

(*a*) The supervision of the running drive.

(*b*) The treatment necessary for any difficulties encountered during the running of rope drives.

(*c*) The care of the ropes in use on the drive, both under normal and extraordinary circumstances.

(*d*) The care and storage of driving ropes not in actual use.

Under normal conditions the duties involved under heading (*a*) are very simple, as has been already explained in Chapter III. The extra precautions needed under abnormal conditions will be mentioned under one or other of the following headings.

Rope drives are singularly free from an inherent tendency towards any particularly troublesome ailment, but under heading (*b*) it behoves us to examine symptoms and prescribe treatment for all the diseases, common and rare, found among rope drives.

In the first place we will consider oscillating ropes, as this is not an uncommon occurrence on account of the fact that only a rope drive will continue to run with the violently fluctuating loads or large regular cyclical speed variations sometimes encountered in practice.

By rope oscillation is meant rope vibration of any kind. It may be pure wave motion longitudinally along the ropes or merely side swinging. In most cases both are combined.

The oscillation may be of large or small amplitude, depending upon many varying factors ; in many cases the vibrations induced are not sufficient to cause any trouble.

The only danger attending on rope oscillation is that the amplitude may be sufficient, combined with a side swing, to cause the ropes to leave their grooves. When this occurs, then, of course, there is always the possibility that ropes may come off the pulleys altogether, and such an occurrence must be guarded against.

Very severe rope jumping also causes an accelerated rate of wear in the ropes. The proper remedy depends upon the cause of the oscillations. A regular rhythmical undulation in the ropes nearly always indicates a cyclical speed variation in one of the pulleys. The source can be found in most cases by observing in what direction the waves travel along the ropes.

If it is an engine drive, a further test can be made by timing the period of the waves to see if they correspond with or are a simple multiple of the beat of the engine.

The remedy in a case of this kind is to provide more flywheel effect at the end of the drive responsible for the oscillation. Moderate cases of this type of disturbance are not harmful, and frequently exist, the resilience of the ropes counteracting any ill influence.

Rolling mill drives, and other classes of work, where the load is necessarily fluctuating and subject to sudden peaks of short duration, require a certain amount of flywheel energy to even out these loads somewhat, as previously described in Chapter VI., and the ropes will largely absorb the remaining shocks. Often, however, the flywheel provided is inadequate for the conditions, the magnitude of the load variations being often indeterminate beforehand. When this occurs, there is danger of the ropes being thrown off the pulleys, and if the provision of more flywheel weight is impossible, the rope guard is the only effective preventive left. This is illustrated in Fig. 80, the section of the blade being shown at Fig. 81 (see page 126), and the correct position on a drive at which to fix the guard is shown in Fig. 82 (see page 126). When the rope jumping is exceedingly severe, it is advisable also to place a guard at the point of entry of the tight side of the ropes on to the driving pulley.

The function of the guard is to control the vibrations of the ropes and to prevent any side swing. The slight friction between the rope and the blade very considerably reduces the amplitude of the vibrations. The guard should be fixed at some distance from the pulley, which is not a simple sub-multiple or factor of the total span of the rope.

It sometimes happens that a drive which has little disturbing influence to cause severe transverse vibrations is, nevertheless, troubled by ropes " rambling " from their grooves. This may be due to the pulleys having too much lateral movement or " float," and should most certainly be corrected if possible.

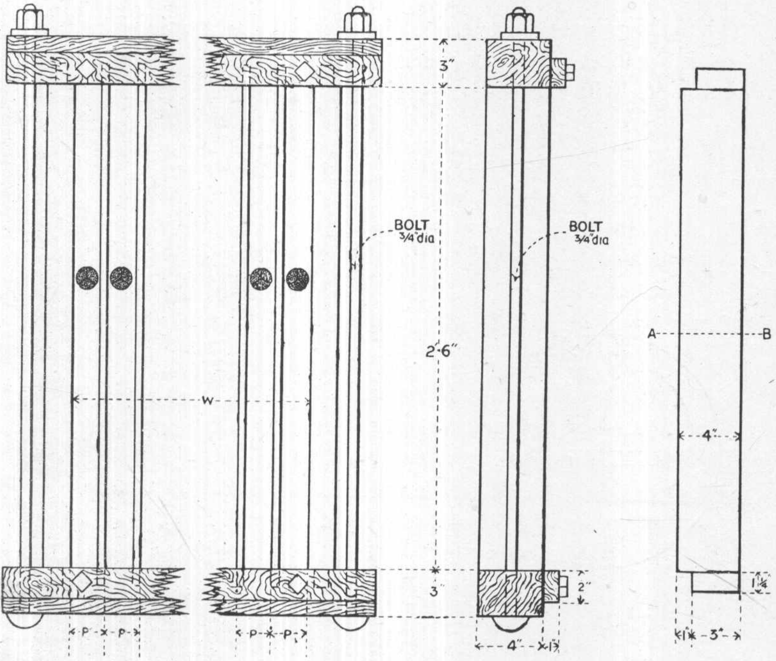


Fig. 80.
Rope Guard.

Again, pulleys running out of truth or eccentrically on their shafts may produce rope jumping, and can easily be detected by an examination of the pulleys themselves. Bent or strained shafts are another cause sometimes encountered. The only real remedies in any of these cases is the replacement or correction of the offending member.

Occasionally it is found that bad splices executed by an inexperienced man are much larger in diameter than the solid rope ; this may produce some oscillation, and since it may also have other bad effects, it should at once be remedied.

Then there is the very remote possibility of harmonic vibration, or resonance. This is when some regular disturbing force coincides with the natural period of vibration of the ropes or rope. Then, of course, nothing on earth can keep the ropes on the pulleys, and some factor in the drive must be altered. Generally, this is accomplished by altering the speed of one shaft and installing a larger or smaller pulley to give the same rope velocity.

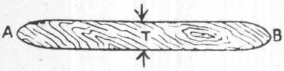


Fig. 81.
Section of Blade for Rope Guard.

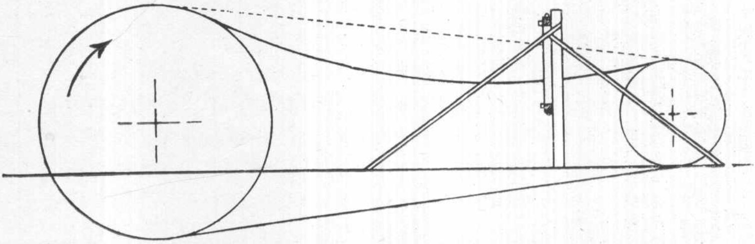


Fig. 82.
Showing position for fixing Rope Guard.

Flywheels and rope guards are practically powerless to assist in cases of this kind. Fortunately, such combinations of circumstances are extremely rare, two only having come within our total experience.

Weak shafts are often the cause of trouble with rope drives, torsional vibration in a rotating shaft causing very peculiar phenomena in the ropes. Sometimes it is found that a wave is produced in the slack side of the ropes, which travels only very slowly along or even may remain stationary, as may be tested by holding a stick close to the ropes. This will not be touched, proving that waves do not travel along the ropes, as is usually the case.

Such a phenomenon as this can probably be explained as follows : Rapid vibrations in one pulley send waves along the entering rope, the velocity of the rope being equal to or approximately equal to the speed at which the waves travel ; the one balances the other. It is not always dangerous, and is usually due to torsional vibrations in the driven shaft. A stiffer shaft should be installed if possible ; a flywheel will help, but a rope guard is generally the remedy adopted, this preventing the ropes from leaving the pulleys.

Occasionally ropes are very lively through being underloaded. If the power or the impulse is rather erratic and the number of ropes too great for the conditions, irregular jumping may be set up. The best remedy is to reduce the number of ropes, but not below the necessary quota to transmit the average load with the usual margin for peaks. Failing this, a rope guard, again, is the best insurance against serious damage.

It is sometimes mistakenly believed that using a larger size of rope will deaden rope vibrations. Except in very special instances this is not the case, and the effect of such a procedure is often to cause more serious trouble.

A jumping rope can often be controlled and steadied temporarily by holding a smooth wooden stick against it.

Warning of displaced ropes is given by the simple expedient of a " knocking-off stick," which we advise for all cases where there is any tendency for the drive to cause jumping ropes. This is a plain, smooth stick of wood about three-quarters of an inch in diameter and pointed at the ends. It is fixed in a position parallel to one of the pulley rims and about one inch away from the ropes, so that if any rope rises out of its groove, it is bound to knock away the stick. The stick itself should be held lightly by pressure in two pads of wood slightly socketed to receive the pointed ends. At very slight expense an arrangement can be made whereby an electrical contact is made when the stick is knocked away and a bell so rung. This gives audible notice of a displaced rope, which can generally be put back into its right groove by an experienced man without stopping the drive.

Rope service is sometimes impaired by " differential driving." This is produced when ropes have different effective diameters on one pulley of a drive. The effect is that some ropes run tight on what should be their slack side, or, as it is often termed, with " slack side reversed." This is usually only noticeable when there is some appreciable difference between the diameters of the driving and driven pulleys.

It is rather a bad thing for ropes, since there must obviously be some slip, and a fraction of the ropes have to do the work of all.

" Differential driving " is the result of either different diameters of rope running side by side on the same drive, or pulley grooves of different contours. The latter cause should never exist, since rope pulleys can and should be made with all their grooves identical in shape and size.

Ropes of different diameters cannot be disposed of so readily, because it frequently happens that some ropes have to be replaced before others on any drive, and the new ropes are generally a little larger than the old ones which may have worn down. The ill-effect of " differential driving " can be reduced to a minimum, if not entirely avoided, by using a good, solid, *standardised* driving rope which is guaranteed to have a certain diameter at its correct working tension. Such is the PATENT INTER-STRANDED COTTON DRIVING ROPE. Even so, however, one of these ropes wears a little as the years pass by, and a new rope put on to replace one which has failed will, of course, be exactly the same diameter of the original set.

This can be avoided by forethought on the part of the rope-user ; if he would mention the circumstances when ordering the replacement rope, the latter could be supplied at a special size to match exactly the existing ones.

In a great many cases it is best to run a set of ropes until they are quite worn out and to re-clothe the drive completely with a new set. The margin of the drive will almost certainly be such that it can continue to transmit its full power without slip, even after a number of ropes have gone.

In other cases, where the conditions are more exacting, it may be most economical to remove the old ropes *en bloc* as soon as they show signs of failure, and to hang them over the bearings or shafts. Re-clothe the drive entirely and have the splicer make up the old ropes again to the best of his ability, making, perhaps, two new ropes out of every three taken off, with two fresh splices in each. These ropes will then serve as spares for when the second set ultimately begins to fail, and since the amount of wear would be about the same in both cases, the spare ropes so obtained could be put to run with the others without any fear of differential driving taking place.

Do not, above all things, think that differential driving can be eliminated by fancy pulleys or grooves. All those so far invented have been not only useless but harmful.

Ropes sometimes rub against the floor of their rope race or against some obstruction such as a beam, or low wall, which originally seemed quite clear. This is because insufficient clearance has been allowed. At least five per cent., and, if at all possible, 7½ per cent. of the centre distance should be left quite clear beneath the centre of the slack span when tight. Less space than this means that the ropes will trail before they are sufficiently slack to re-tighten.

When such trailing occurs, it is best to obtain the opinion of an expert splicer to see if it is possible or advisable to take the ropes up. If not, then either a deflecting guide pulley should be used to keep the ropes from the obstruction, or else smooth, polished running boards of hard wood should be laid down for the ropes to rub along. This board should be laid with its grain in the direction of the ropes, and should be treated regularly with rope dressing. Never use rollers or metal bars for this purpose, or drums with flat rims ; if a deflecting pulley is used, it should be of ample diameter as specified in Table VI., and should be provided with the standard guide pulley groove as shown in Fig. 77 (see page 120).

Ropes sometimes fray rapidly on the surface, and an increased rate of surface wear is indicated by the emission of cotton fibre as " fluff." Such fluffing should never exist, and when it does it indicates that some agency is producing an unhealthy rate of surface wear on the ropes. It should be looked for among the following things :—

(*a*) Ropes rubbing against some obstruction.
(*b*) Rough pulley grooves.
(*c*) Unsuitable form of pulley grooves.
(*d*) Pulleys severely out of alignment.
(*e*) Pulleys too small for the rope (see Table VI.).
(*f*) Drive running among a lot of grit or dust.
(*g*) The kind of rope.

Causes (*a*), (*b*), (*c*), (*d*) and (*e*) have already been discussed in detail in different parts of this book. If the proper remedy cannot be applied at once, a frequent and fairly liberal treatment with good rope dressing will often alleviate the complaint.

If the cause is a gritty atmosphere, the best course to adopt is the simple one of protecting the drive from this deleterious influence. This is done by encasing it in a dust-proof rope race. Should that be impossible, it becomes necessary to brush the ropes regularly along the lay of the fibres, afterwards applying rope dressing. Never apply dressing without brushing first.

Lastly, if the rope is one which has " crinkled threads " (of which more later) inside, then the surface will soon be broken up and fluffing will result. Or if the rope is too soft or made with an unsuitable construction or from inferior material, "fluffing" is bound to occur in spite of all human endeavour. In this case the only course open to prevent the trouble is the replacement of the ropes by a good set of solid and durable ones.

It will be as well here to mention that a merely " hard " rope is not necessarily a durable one, but often the reverse ; to distinguish a good rope the reader is referred to the next chapter.

Many rope users have doubtless noticed at some time or other that all ropes are not in the same condition even on the same drive. Some soon become perfectly round, smooth and polished, whilst others become slightly wedge-shaped and a little " fluffy " in appearance.

The former are termed " revolving " ropes, whilst the latter are " fixed." That is to say, revolving ropes are those which turn over in their grooves, whilst the " fixed " ones are those which always assume the same position when in their grooves, until flats are worn along the two sides.

Experience shows that fixed ropes last longer than the revolving ones ; the argument that the more evenly distributed wear around a revolving rope tends to make it last longer being disproved by actual practice. The real explanation is that in a revolving rope the splice is subject to continual torsion, whilst in the fixed rope this is not the case ; surface wear is not of supreme importance, because a good rope always fails first through the splice coming undone. A scientifically constructed rope like the PATENT INTER-STRANDED COTTON DRIVING ROPE will continue to pull up to the last few threads, provided its splice holds.

It is therefore advantageous to have ropes " fixed," but, unfortunately, there are so many factors which have influence on this that even the most experienced splicers cannot always guarantee a rope to " fix " in its groove.

The drive shown in Fig. 83 affords a good example of revolving and fixed ropes. The polished looking ropes are revolving, whilst the remainder are fixed.

When ropes do come off a drive or have to be taken off for any reason, the greatest care should be exercised in putting them back again. Full instructions about this are given in a separate booklet of ours, "The Fitting of Endless Ropes over Pulleys," to which reference should be made by those compelled to do this work. It is advisable, whenever possible, to stretch ropes which have been off a drive for any length of time so that they will go on easily.

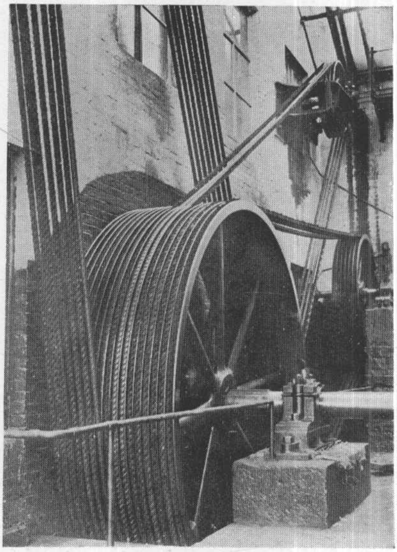


Fig. 83.
Revolving and Fixed Ropes.

Never attempt to put on a rope without first putting a smaller diameter "slip rope" in the bottom of the pulley groove so that the rope going on may slip in its groove. For the same reason, the groove should be well greased. Bagging should be put between the rope and the edge of the pulley rim at the point where it goes on, in order to prevent the rope from being bruised. Fig. 84 shows the operation of fixing a rope on the drive.

Splices should never be tampered with, and certainly not undone, since it is then impossible to make up the rope again to the same length. We publish a separate booklet on "Splicing," which is intended for use abroad where skilled driving rope splicers are sometimes difficult to obtain. In this country it is advisable to obtain the services of the splicers employed by the makers of the rope used.

When ropes have to run in moist or gritty atmosphere, it is strongly advisable to treat them liberally with our Special Rope Composition. The special precautions for gritty atmosphere have already been mentioned. All other conditions merely necessitate an occasional dressing with the composition used very sparingly. This should always be done when the ropes are stationary if possible. Rope composition of a resinous or of a semi-liquid consistency should be shunned as it is injurious to good cotton driving ropes.

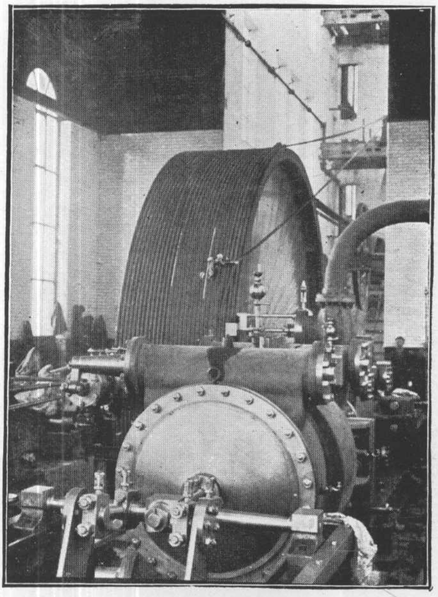


Fig. 84.
Fixing Rope on Drive.

Drives have occasionally to stand without running for appreciable periods, and in these circumstances it is often found that the ropes shrink tighter due partly to the absorption of moisture from the atmosphere, and partly due to the inherent property of recuperation in most good cotton driving ropes. This can be avoided by "Blocking" the ropes on shutting down, *i.e.*, inserting blocks of wood between the ropes and pulley, as shown in Fig. 85 (see page 134). These blocks should be smoothed over. On starting up the drive the blocks should be carefully removed by barring the drive round, when it will be found that the ropes are at a nice, easy tension.

Ropes not in use should always be stored in a fairly warm, dry place which is well ventilated. They should be coiled up and laid on baulks of timber or duck-boards so that air may circulate underneath them. On no account should rope be stored flat on earth or concrete floors, nor should odd lengths be hung on nails.

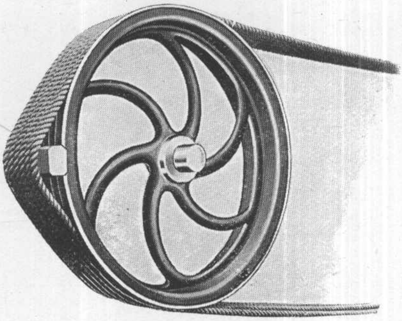


Fig. 85.
"Blocking" Ropes.

Care should be exercised in taking rope from coils; the best method is to put the coil on a horizontal axle and spin it round. If this is not possible, lay the coil flat on the ground in a manner so that the free end uncoils from the outside in a counter-clockwise direction, otherwise twist will be put into the rope which will, in consequence, become almost unmanageable.

CHAPTER VIII.

THE ROPE

THERE now only remains to discuss the most important point of all, the selection of a good driving rope. When all is said and done about design of drives, construction of pulleys and whatnot, this consideration is still the vital one concerning the service, efficiency and life to be obtained from a drive.

It is not the slightest use putting a cheap or unsuitable rope on a good drive, just as it is wasteful to use any kind of rope on a badly arranged one. On the other hand, however, a good rope will pay for its extra cost under either condition.

The most extravagant policy in rope driving is to use cheap rope ; and next after this, to use cheap pulleys.

Now, in considering the rope, it should be borne in mind, firstly, that whilst there are many different kinds and makes of rope on the market, there are very few *driving* ropes ; and secondly, that the quality and uniformity of the material used in the rope is more important than any other consideration.

The rope we recommend for all rope drives is " Kenyon's PATENT INTER - STRANDED THREE - STRAND COTTON DRIVING ROPE," popularly known as " P.I." Rope.

Extensive experience proves beyond the slightest doubt that cotton is the best fibre for driving ropes. Manilla and hemp ropes soon went out of vogue for driving because of their rapid wear and permanent stretch, due to the harshness and lack of elasticity in their fibre.

The three-strand rope is recommended and most popularly used because, again, experience has proved its superiority over ropes with larger numbers of strands.

The three-strand rope is more stable than any other form, its strands being held in equilibrium on the principle of the triangle of forces; the section (see Fig. 86) shows how compact is the construction.

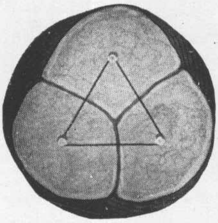


Fig. 86.
Section of Three Strand "P. I." Rope.

The less the number of strands the less is the amount of internal wear, so that the three-strand rope has a further advantage in this respect. Greater ease in splicing and the equalisation of stresses are two further points in favour of the type we recommend.

Our Patent Inter-stranded construction enables the rope to be built up solidly in such a manner that every yarn in the rope contributes its full share towards bearing any load or doing any work.

It is always advisable to open out a strand from any driving rope being examined, in order to inspect the inside threads. In nearly all other ropes than "P.I." it will be found that these are "crinkled," as shown in Fig. 87. This is due to the wrong method of construction employed, whereby the rope is merely twisted up from a number of parallel threads instead of being built up, layer by layer, as is the "P.I." rope. Any person not already acquainted with this property of "P.I." ropes may easily test it for himself by opening a sample of our rope.

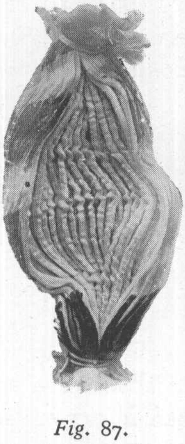


Fig. 87.
Opened strand of ordinary rope showing crinkled threads.

It will be obvious that such crinkled inner threads are incapable of resisting any tensile stress until pulled out straight. The outer threads thus have to bear all the load at the commencement, and, being overstressed, they stretch rapidly and break up until the inner threads take their share of the load. This produces an excessive "wearing stretch" in the rope, a very troublesome property, and also in fluffing due to the breaking up of the outer fibres.

"P.I." ropes, having their threads laid correctly into place in the strands under a correct tension, are quite free from this.

There is a slight stretch in all ropes which follows upon wear due to the elongation of the spiral of which each strand consists. In a correctly made rope this is so slight as to be in practice negligible, except after long service, when the ropes may be tightened by resplicing. On a drive of good design "P.I." ropes will run their life with a maximum of one tightening by resplicing, and in most cases not even this is necessary.

On the other hand, a "crinkled" rope starts to stretch and continues to do so indefinitely because all its fibres are never in action simultaneously.

The Patent Inter-stranded Cotton Driving Rope, therefore, is practically free from "wearing stretch," and possesses a minimum of "initial stretch." Furthermore, each fibre taking its proper share of the load all the time, the rate of elongation under increasing load, as obtained on a testing machine, is very regular, and is always the same for any given diameter. The resilience possessed by the "P.I." rope under these conditions is very high, being nearly twice as much as an ordinary twisted cotton rope and three and a half times as great as that of manilla. This subject is too wide in scope to be dealt with here; those interested are referred to our booklet on the "Strength and Properties of Fibrous Ropes."

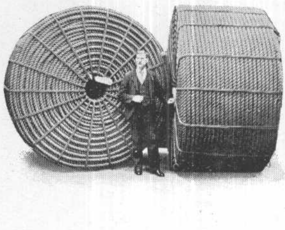
The solidly built "P.I." rope is, by virtue of its very compactness, less liable to be affected by atmospheric variations than any other.

When a strand has been opened, after the examination for "crinkling," the yarns themselves should be examined. In a good rope these must be of a good quality; they must, in fact, be perfect yarns and not "rejects" of any kind. They must also be uniform in counts, *i.e.*, in size, as well as in their direction of twist. Any rope which has yarns of different sizes, twists or varieties should be rejected, because it cannot give good service.

Since it is always being bent when in use it naturally follows that a rope requires some lubrication. This is usually supplied on the rope to begin with, and *must* be *between* the strands if it is to be effective. The outer surface soon has its lubricating dressing rubbed away, and should then be recoated sparingly, but the inside surfaces retain their lubricant. "P.I." ropes are lubricated during course of construction.

Another very important point about driving ropes is that they should be at their specified diameter when actually on the drive under tension. It necessarily follows that the rope must be slightly larger than its normal diameter when in coil. There are few ropes other than "P.I." which possess this property, but we will actually guarantee the Patent Inter-stranded Driving Ropes to be the diameter specified *when fixed on the drive* under usual conditions of tension, etc. This is termed "standardisation," and it ensures that when new ropes are required they will all be exactly the same correct size on the drive.

It is scarcely necessary to say more in this chapter. We leave the reputation of the "P.I." rope in the hands of its many users. The records of drives quoted earlier in the book prove what durability is possessed by it, whilst the tremendous quantity used annually in every country under the sun demonstrates very strikingly how general is its use.



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